P O R K
P R O D U C T I O N

W I L L I A M W . S M I T H , M . S . A .

Professor Emeritus of Animal Husbandry
Purdue University

WITH A CHAPTER ON *Sanitation and Disease Control*

by L . M . H U T C H I N G S , D . V . M . , P H . D .

Professor of Veterinary Science
Director of Animal Disease Diagnostic Laboratory
Head of Department and Chief Veterinarian
Purdue University Agricultural Experiment Station

T H I R D E D I T I O N

T H E M A C M I L L A N C O M P A N Y : N E W Y O R K

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Preface

In the preparation of this third edition of *Pork Production,* the author has been guided, as he has in the past, by the wish to present information and suggestions which will be of practical help to the hogman and student. To bring this information up to date, as nearly as this is possible, has involved the review of an ever-increasing volume of experimental data. These studies, extending over 15 years, have brought to light many significant new facts and ideas, not only in the field of nutrition, but also in the realms of breeding, marketing, sanitation, and disease control. He expresses the hope that his efforts in the organization, selection, and presentation of this new material will be of value to the student of pork production and of service to the practical feeder and breeder.

In its preparation the author has been the recipient of much help and many courtesies for which he wishes to express grateful acknowledgment. To Dr. W. M. Beeson of Purdue University, who read several chapters and made critical suggestions and who was constantly consulted on questions of nutrition, he feels particularly indebted. He wishes to express his appreciation to Dr. J. A. Hoefer of Michigan State College for his many helpful suggestions. He is indebted to Dean E. C. Young of Purdue University for his critical reading of the chapter on prices; to Professor M. Paul Mitchell for much information on markets; to Dr. Fred N. Andrews for suggestions and information on reproductive physiology, and to members of the department of Agricultural Economics, Purdue University, for much statistical and other information. Grateful acknowledgment is made to the Bureau of Agricultural Economics, the Office of Foreign Agricultural Relations, and the Bureau of Animal Industry of the U.S. Department of Agriculture for their courtesy in supplying graphs and much statistical data. Special acknowledgment is made to Professor F. B. Morrison of Cornell University for permitting extensive use of the feed composition tables in "Feeds and Feeding." And, finally, the author wishes to express his appreciation and thanks to the many friends who collaborated by supplying unpublished data and photographs.

The author is happy to have been able to secure Dr. L. M. Hutchings to write the chapter "Sanitation and Disease Control."

PURDUE UNIVERSITY *W. W. SMITH*

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I General View

The important position which the hog occupies on the American farm is attested by the fact that 24 percent of the world's number is produced in the United States (see Fig. 1).

Swine are produced in largest numbers in those countries which have a relatively dense population. The leading pork-producing areas outside the United States are Central Europe, China, and Brazil. The United States, Denmark, Canada, the Netherlands, and Poland normally are the principal surplus-producing nations, while Great Britain, Germany, France, and Belgium are the principal deficit countries. Up until very recent years, imports of pork products by England exceeded those of all other European countries combined. Pork production in Soviet Russia in the years from 1946 to 1948 was less than one-third of what it was immediately before World War II (1936–1940). During the same time Germany's production declined by one-half, and in France by one-fourth; United States production during the same period increased by 16 percent.[1] However, substantial increases in number have occurred in most of the European countries and in Soviet Russia since 1948.

Although this country still produces a surplus of pork and lard, exports to European countries have steadily declined since 1920, except those required for war and to meet postwar commitments. This decline has not been due to any lack of capacity to produce on the part of the American farmer, but rather to disturbed trade relations and the impoverishing effects resulting from two world wars.

DISTRIBUTION OF SWINE IN THE UNITED STATES

The production of swine in the United States is closely linked with the acreage of maize or Indian corn. Although hogs are raised in all the states, 70 per cent is produced in the Corn Belt.[2] More than 80 per-

[1] Reginald G. Hainsworth, *A Graphic Summary of World Agriculture*, U.S.D.A., Misc. Pub. No. 705, 1949.

[2] *Livestock and Meat Situation*, Bureau Agr. Ec., U.S.D.A., LMS-46, Dec., 1950.

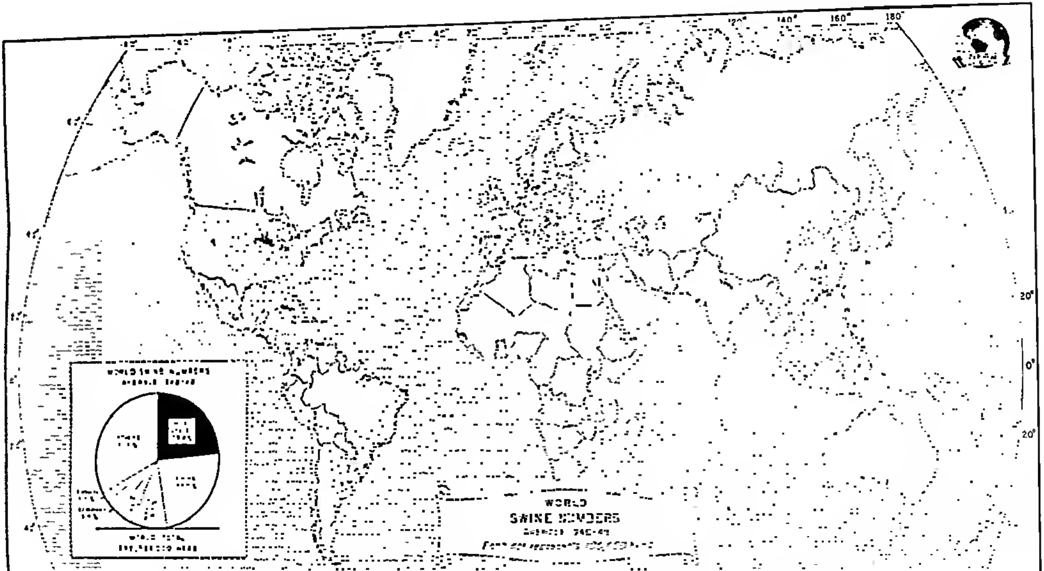


Fig. 1. World distribution of swine (*U.S.D.A., Office of Foreign Agricultural Relations*).

cent of the commercial pork supply is grown in this area. The state of Iowa alone produced 20 percent of the entire nation's production during the period 1946 to 1950. The distribution by areas during this 5-year period was as follows: West North Central states, 42.8 percent; East North Central, 29.6 percent; South Central, 13.8 percent; South Atlantic, 8.7 percent; Western, 3.1 percent; and North Atlantic states, 2.0 percent.

Swine production in these different districts has remained relatively constant except for the Western area. Here, despite the tremendous population growth on the West Coast, the number of hogs produced in 1948 and 1949 (number on farms, Jan. 1) represented a decline of more than 20 percent compared with the 10-year average production from 1938 to 1947.[3] This increased demand in the Far West, with reduced production, has resulted in a marked increase in the number of hogs shipped to West Coast markets in recent years, and consequently to an improvement in hog prices in Omaha, Sioux City, Kansas City, and St. Joseph, as related to the prices paid in Chicago. In New England and other Eastern states, population growth continues to outrun pork production. In the Corn Belt, there is about one hog produced for each individual, whereas in New England and the Mid-Atlantic states the ratio is one hog to 16 members of the population.

From 40 to 45 percent of the corn grown in the United States is marketed as pork. The greatness of this cereal as a farm crop is in large measure the result of its extensive use as a hog feed. Growing corn and producing pork have been combined to make the farmers in the upper Mississippi valley the wealthiest agricultural people on the globe. Hogs contribute a large share to the total farm income. In Iowa, the value of the hogs sold and home-consumed in 1948 and 1949 represented 38 percent of the total cash income; for Indiana, the figure was 31 percent; and for Illinois, it was 23 per cent. For the entire nation, proceeds from the sale of hogs represented 13½ percent of the total gross agricultural income.

FACTORS FAVORABLE TO PORK PRODUCTION

The important position which the hog occupies on the American farm has been gained through his inherent ability to render a profit above the costs of production. These profits are due to certain advantages which the hog enjoys as a producer of human food and to the popularity of pork in the American diet. In the following paragraphs most of these advantages are separately enumerated.

[3] *Agricultural Statistics*, U.S.D.A., 1949.

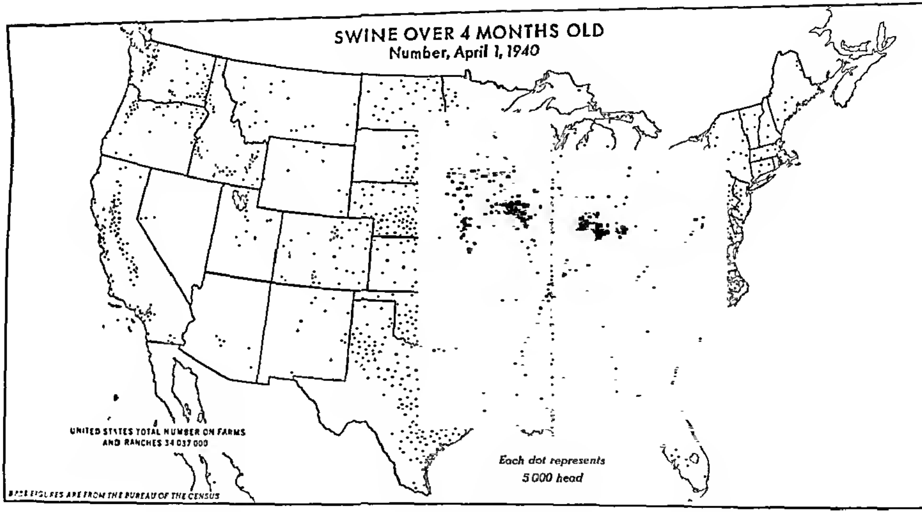


Fig. 2. Distribution of swine in the United States (*U.S.D.A., Bureau Agr. Economics*).

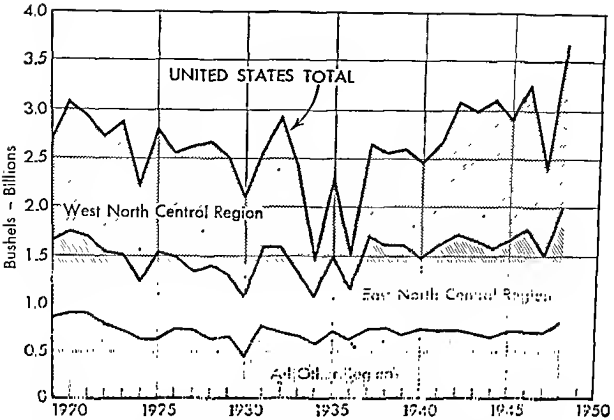


Fig. 3. Corn: production in the United States and selected regions, 1919–1948 *(U.S.D.A., Bureau Agr. Economics).*

1. The demand for pork is wide and insistent. Excepting dairy products, no animal food is so necessary in the diet or so universally used. In this country more pork is eaten than any other meat. Pork and lard supply between 15 to 16 percent of the total food calories consumed in the United States. Forty percent of the fat contained in the diet is derived from pork and its products. The average per capita consumption of the different meats and lard is shown in Table 1. There is no evidence in these figures of a declining trend in meat consumption. So long as people are prosperous they will continue to buy this high-priced high-value food.

Table 1. The Annual Per Capita Consumption of Meat and Lard in U.S. by Five-year Periods, 1915 to 1949[4]

	1915–1919	1920–1924	1925–1929	1930–1934	1935–1939	1940–1944	1945–1949
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Beef	61.5	58.1	54.1	51.6	55.2	56.8	63.1
Veal	6.9	7.9	7.3	7.2	8.1	8.7	10.7
Mutton and lamb	5.3	5.4	5.4	6.8	6.8	6.7	5.7
Pork	63.4	67.9	67.4	67.8	56.1	72.4	69.5
Total meat	137.1	139.5	134.3	133.4	126.2	144.7	148.4
Lard	11.5	13.2	12.8	13.6	11.0	14.0	12.9

[4] *Livestock Market News*, Bu. Agr. Ec., U.S.D.A., Stats. Bul. No. 91, 1950

2. Hogs sell at relatively high prices. Pigs can be sold at weights ranging from 175 to 300 pounds with little sacrifice in price. The feeder, therefore, is comparatively free to take advantage of a good market by selling early or of feeding to heavier weights when the prospects for a better market are good. In the case of yearling and older steers, and lambs particularly, the feeder is restricted to a much narrower range of time and weight in marketing. The market value of old sows which have done service in the breeding herd is higher than it is for cows or ewes. Although sows are subject to a dock of 20 to 40 pounds, frequently they sell for more after finishing a long career in the breeding herd than they had cost at the beginning.

3. Pork is produced economically. No other meat-producing animal on the farm produces human food as economically as the pig, despite the fact that concentrated foods necessarily make up the major part of his ration. The initial cost of the pig at birth is much less than it is for the calf or lamb, and the cost of the subsequent weight gains is in favor of the pig. The figures below represent the approximate average amount of feed that is required to produce 100 pounds of gain during the market-finishing period of steers, lambs, and pigs.

750-pound fattening steer	650 pounds grain + 450 pounds legume hay
65-pound fattening lamb	400 pounds grain + 500 pounds legume hay
150-pound fattening pig	425 pounds grain

When to this is added the pig's ability to convert rapidly into pork such refuse as kitchen garbage, the undigested corn in the droppings of cattle, damaged grain, and dairy by-products, his efficiency is further emphasized.

4. Pork production supplements efficiently the other types of livestock farming in the Corn Belt. Hogs are essential to successful beef production. The pork produced from the grain that has passed through the cattle is clear gain and one of the most important profit-determining factors in cattle feeding. For every bushel of corn, fed shelled or on the ear to steers, the hogs following will produce from one to two pounds of pork; when the grain is fed cracked or as meal, from a quarter- to a half-pound will be produced. Beef cattle are roughage consumers, while the pig requires concentrates. Beef production and pork production on the same farm do not involve serious labor competition. Dairy farming cannot be conducted along the most efficient and profitable lines without a sufficient number of hogs to utilize the skim milk, buttermilk, or whey which may be available for feeding, and the undigested grain in the droppings of the cows. It is doubtful

whether any type of farming can as easily be made to satisfy all the tenets of good farm management as a well-conducted dairy which depends on its output of cream or butter and pork for its principal revenue.

5. It does not require much time or money to get a start in the hog business. The large number of pigs produced in each litter, the relatively short gestation period, their capacity for quick growth, the possibility of raising two litters a year, and the rapidity with which the gilts attain breeding age contribute to this result. The initial investment in starting a herd of hogs is less than for other classes of livestock, the turnover is quicker, and the opportunity for selection and improvement in a given time is consequently much greater.

6. Pork can be more successfully cured and stored than other meats. At the present time 60 percent or more of the hog carcass is converted by the various processes of curing into nearly nonperishable forms. Packers are thus enabled to carry over to seasons of short supply the accumulation of periods of excessive or heavy receipts. As a consequence of this, the heavy market receipts which normally occur during the winter do not have the demoralizing effect on prices that they would be sure to exert if, like beef and mutton, the pork carcass had to reach the consumer within a period of a few weeks.

7. The necessary equipment for the successful handling of a herd of hogs is neither extensive nor expensive. This is particularly true when early pigs are not attempted. Suitable shelters must be provided for early-farrowing sows, but they need not be of a kind which would mean a burdensome overhead expense. Hogs are more susceptible to extreme heat than any other farm animal, but the cost of appropriate shades is little more than the time required to erect them.

8. The labor cost of producing pork is low when volume production is combined with good farm organization, suitable fencing, and adequate watering facilities. With the wider use of the self-feeder for pigs intended for an early market, the substitution of dry for slop feeding, and the more general appreciation and use of forage crops for all classes of hogs, labor costs may be materially reduced.

LIMITATIONS AND HANDICAPS TO PORK PRODUCTION

On the other hand, there is no class of farm livestock that is subject to such a heavy toll of losses, resulting from a failure to follow good sanitation and disease-prevention practices, as the hog. The annual loss from cholera alone is enormous. Infestation with parasites exacts

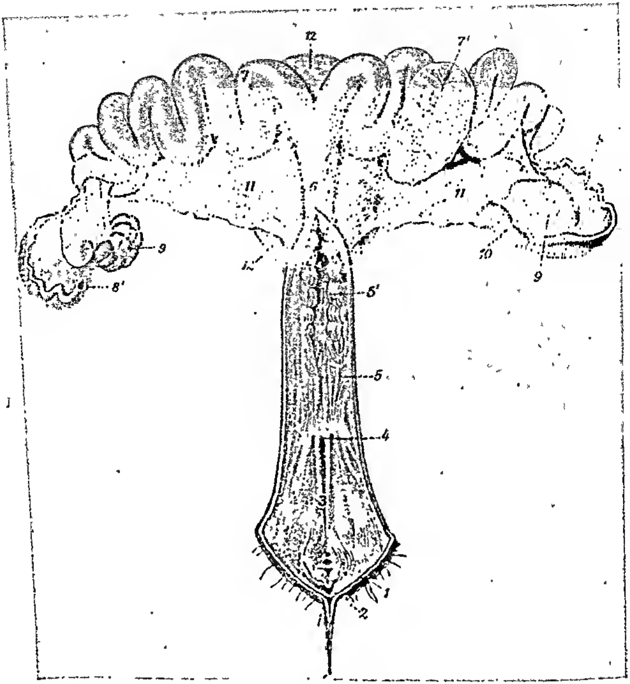


Fig. 4. Genital organs of the sow; dorsal view. The vulva, vagina, and cervix uteri are split open. 1, labium vulvae; 2, glands clitoridis; 3, vulva; 4, external urethral orifice; 5, vagina; 5', cervix uteri; 6, corpus uteri; 7, cornua uteri, one of which is open at 7' to show folds of mucous membrane; 8, uterine (Fallopian) tube; 8', abdominal opening of tube; 9, ovaries; 10, ovarian bursa; 11, broad ligaments of uterus; 12, urinary bladder *(from Sisson's* Anatomy of Domestic Animals; *originally from Leisering's* Atlas*)*.

season, if not bred. Rice [a] observed that the heat periods recurred on the twenty-first day more frequently than any other. Exceptions are found among sows which lack breeding thrift and those which are nursing pigs. Sows sometimes come into heat a few days after farrow-

[a] J. B. Rice, Ills. Exp. Sta., Duroc Jersey Bulletin, June, 1921.

ing, usually the third, and frequently again during the later weeks of the nursing period. Normally, sows come into heat three or four days after their pigs are weaned.

Trials by Robison [4] showed that sows may be bred and safely settled while still nursing their pigs. This he accomplished by separating the sows from their litters at night, allowing them to be together during the day as usual. During three spring and one fall season a total of 15 sows was thus bred and later farrowed. Heat usually appeared after the fourth or fifth night of separation. In only one case in the 16 tried did the treatment fail. The litters ranged in age from 43 to 56 days when the mothers were bred.

The possibility of encouraging nursing sows to come into heat during the later days of lactation by turning the boar in with them is indicated by its frequent practice among farmers. Breeders claim that nursing sows are more likely to come into heat when self-fed than when hand-fed. Cole and Hughes of California University [5] demonstrated that estrus, or heat, could be induced in nursing sows by the injection of 1000 I. U. gonadotropin, a hormone derived from the blood serum of pregnant mares. Forty-two sows were treated in this manner. Summarizing, Cole and Hughes state: "Sows which were injected in early lactation (1 to 38 days) did not manifest estrus regularly, but 26 of 27 sows injected between the thirty-ninth and sixty-eighth days of lactation came into heat three to seven days following treatment. All of these animals were bred. Twenty of 23, on which information was available, became pregnant during this induced estrus." These authors question the possibility of inducing heat in nursing sows by turning the boar in with them. They allowed a boar to run with four control lactating sows, starting between the twenty-second and forty-fourth days of lactation. None showed any evidence of having been bred and none became pregnant.

Vitality of germ cells. Researches by Lewis of the Oklahoma Station [6] on the vitality of germ cells indicate that the ripened eggs, or ova, are not discharged from the ovaries until the latter end of the heat period. Marshall and Hammond [7] say the eggs are shed 30 to 35 hours after the beginning of heat. These scientists also observed that the eggs do not retain their vitality, unless fertilized, for a period longer than a few hours after being liberated. Lewis' studies also indicated

[4] W. L. Robison, Monthly Bulletin, Ohio Exp. Sta., Vol. III, No. 5.
[5] H. H. Cole and E. H. Hughes, *Jr. An. Sc.*, Vol. V, No. 1, 1946.
[6] L. L. Lewis, Bul. 93, 96, 1911.
[7] F. H. A. Marshall and John Hammond, Min. of Agr., Bul. 39, 1932.

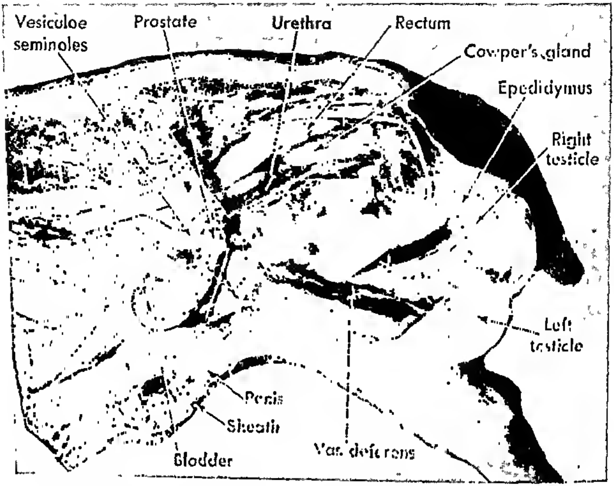


Fig. 5. Genital organs of the boar in natural position *(courtesy, Dr. Fred C. McKenzie and James C. Miller, Mo. Exp. Sta.).*

that the sperm cells of the boar do not, as a rule, retain their vitality in the body of the sow for a longer period than 16 hours after service, and that the eggs probably retain their physiological capacity for fertilization for even a shorter period. In the case of the sperms, much will depend on the individuality of the boar and the frequency of the services. Studies by McKenzie and associates of the Missouri Station [8] showed that when the services occurred at intervals of 48 hours or longer, the sperms remained motile for five or more days; when ejaculations were made at 24-hour intervals or less, the motility was reduced to three days or less (see Chap. XXI). The time that sperms remain motile normally exceeds the duration of their fertilizing effectiveness.

Other studies made at the Missouri Station by Weaver and Bogart [9] showed that gilts bred twice during the same heat (12 to 24 hours between services) had a greater percentage of conceptions and farrowed

[8] Fred C. McKenzie, J. C. Miller, and L. C. Baugues, Mo. Agr. Exp. Sta., Res. Bul. 279, 1938.

[9] L. A. Weaver and Ralph Bogart, Bul. 461, 1943.

more pigs per litter than gilts bred once during heat. Thirty-six of 40 gilts (90 percent) bred twice during the same heat period conceived and farrowed 8.2 pigs per litter; 31 of 43 gilts (72 percent) bred once during heat produced 7.1 pigs per litter. When stored low-quality semen was used for artificial breeding, two inseminations (12 hours apart) during the same heat period gave more than twice the percentage of conceptions than was obtained with one insemination. When the practice is to breed but once during the heat period, service on the second day of heat would seem to be most likely to ensure large litters and a minimum of breeding failures. The safest rule in practice, however, especially when the number of sows to be bred is not excessive, is to allow another service the next day if she is still in heat.

At the Illinois Station Wilson and associates[10] studied the cases of 79 "hard-to-settle" sows and gilts. Of these 42 were settled while on experiment after repeated breedings (average number of services per heat, 3.9); the remaining 37 which failed to settle showed the following genital abnormalities which were believed to be responsible for most of the breeding failures: tubular aberrations, cystic follicles, and blind or missing parts of the reproductive system.

Gross genital abnormalities. Recently Wiggins and associates of the Wisconsin Station[11] examined 5088 mature sows and gilts after slaughter for the presence of gross genital abnormalities. They found that 5.1 percent of the gilts which had reached the stage of puberty and 4.9 percent of the open sows had some gross genital abnormality. The incidences of these were: tubular abnormalities (bursitis and hydrosalpinx), 1.4 percent; cystic follicles plus corpora lutea, 1.1 percent; cystic follicles without corpora lutea, 0.6 percent; missing parts, 0.7 percent; double parts, 0.1 percent; and rudimentary male ducts (computed on 3476 animals), 8.9 percent.

On the assumption that gilts and sows do not differ in reproductive efficiency, the authors suggested that about 25 percent of the breeding failures could be attributed to gross genital abnormalities.

The economic loss which results from breeding failures, amounting to an average approximately of 20 percent of the sows bred, represents a heavy tax on the swine industry. If to this loss there is added the fatalities which occur subsequently during the foetal stage of growth,

[10] R. F. Wilson, A. V. Nolbandrov, and J. L. Krider, *Jr. An. Sci.*, Vol. 8, No. 4, 1949.

[11] E. L. Wiggins, L. E. Casida, and R. H. Grummer, *Jr. An. Sci.*, Vol. 9, No 3, 1950.

from birth to weaning, and from weaning to market time, the total is alarming (see page 71).

Length of the gestation period. The time elapsing between breeding and farrowing is known as the gestation period. During this time each of the fertilized eggs develops into an embryo pig, and with the completion of foetal growth, birth takes place. Normally, the gestation period is just long enough to make possible the full prenatal development of the pigs and to accommodate those physiological adjustments in the sow which are preliminary to parturition or farrowing.

Recent accumulations of data indicate that the average length of the gestation period is 114 days. Records reported from various sources by the author in the second edition of *Pork Production* gave an average of a fraction over 114 days for 1124 gestations. Lush [12] summarized the date for 6535 gestations, the average of which was 114.3 with a standard deviation of 2.2 days. He suggests that a good rule is to suspect as being abnormal any gestation differing from the average by more than the standard variation. Investigators have found no convincing evidence that mature sows carry their pigs longer than do gilts, nor that the season of the year exerts any influence. There may be breed differences, and there is evidence that small litters have slightly longer gestations than large litters.

Age to breed gilts. It has been observed that gilts attain puberty at a comparatively early age in comparison with other species of farm animals. Many research workers and swine producers report that the heat periods generally are initiated between the fourth and seventh months. Studies by Wiggins and associates of the Wisconsin Station [13] indicate that the average gilt attains sexual maturity at a somewhat later age than is shown by earlier data; also, that spring-farrowed gilts reach puberty later than do those born in the fall.

Dean F. B. Mumford of the Missouri Station [14] reported that young gilts bred at the first appearance of heat to farrow at eight or nine months of age stop growing for a time. If they are well fed, and bred only once a year thereafter, they may practically recover from the dwarfing effects of the early gestation; but if not generously fed, or if bred twice a year, even with the best of feeding, they will be permanently affected. It was observed that growth took place at a normal rate during gestation, but none occurred during lactation.

[12] J. L. Lush, *Animal Breeding Plans*, Ia. State Col. Press, p. 396, 1943.
[13] E. L. Wiggins, L. E. Casida, and R. H. Grummer, *Jr. An. Sci.*, Vol. 9, No. 3, 1950.
[14] *The Berkshire World and Corn Belt Stockman*, June, 1921.

Experience has established the important fact also that the first breeding should not be too long delayed. Reasonably early breeding tends to establish reliable breeding habits, while postponement frequently results in the reverse. Furthermore, the earlier the gilt can be made a producer, the larger will be the saving in feed, interest, and risk. As a general rule, the gilt that is well developed may safely be bred to farrow when 12 months of age. When an active gilt has reached the weight of 180 to 200 pounds, she may be bred without danger of sacrificing full development later or her future as a producer. The breeding of fall-farrowed gilts intended for show the following autumn should not be postponed. With the present-day emphasis by judges on evidences of pig-producing ability, they will show to better advantage in the under-year class if well along in pig.

When should the sows farrow? For spring farrowing, the question of early or late pigs must be determined for each farm according to its location, the facilities which it affords in the way of quarters for handling the litters in cold weather, and the main objectives of the farmer and his plan or type of farm organization.

Among the important advantages of early spring farrowing—February and March—are the following: (1) The sows farrow during the season when time is available for their proper supervision and care. (2) Early-spring pigs are weaned at a sufficiently early date to enable the sows to be rebred for the production of fall pigs in September. (3) Early-spring pigs may be off to market early, thus vacating the premises for the fall crop. Early farrowing is practically a necessity on those farms where the two-litter system is followed. (4) Pigs farrowed early may be ready for market in August or September when prices usually are highest. (5) Early farrowed gilts are sufficiently grown by November to permit them to be bred for early farrowing the following spring. (6) The early pigs complete a larger part of their growth while on forage than do late-farrowed pigs and the more expensive period of dry-lot feeding is shortened.

In favor of having the spring pig crop farrowed in April and May, the following may be mentioned: (1) The amount of equipment and labor necessary for the successful handling of late pigs is less than it is for early pigs. (2) Late farrowed pigs are less likely under average conditions to suffer from anemia and the other ills incident to close-housing and worm-infested lots. (3) Late pigs make a larger use of the cheaper new corn than do those farrowed and marketed earlier. (4) Pigs farrowed in April and May have sufficient growth in October

and November to make them particularly satisfactory for following cattle or hogging-down corn.

On those farms which produce only spring pigs, late farrowing is the rule; where the two-litter system is followed, the production of early spring pigs is the common practice. In the western Corn Belt the one-litter system is generally followed, while in the eastern sections the two-litter plan is now almost universally the rule.

Fall-farrowed pigs profitable. On well-equipped hog farms the production of two crops of pigs, one spring- and one fall-farrowed, has a number of advantages. Perhaps the most important of these from the viewpoint of the producer are, first, that the cost of equipment or overhead is less per unit of pork produced, and second, the selling price usually averages higher, because of the fact that a smaller proportion of the year's production reaches market in December and January, the season of normal surpluses. Also, by tending to equalize winter and summer marketings, the two-litter program makes possible greater efficiency and lower costs in getting the products to the consumer. Fall-farrowing sows and gilts, as a result of forage-feeding conditions, have a thrift and an accumulation of vitamin and other food reserves so necessary for the production of strong pigs and the capacity to nurse them generously after birth.

In this connection it is of interest to note that of the pigs raised in the United States in 1948, 60 percent were spring-farrowed (Dec. 1 to June 1) and 40 percent fall-farrowed (June 1 to Dec. 1).[15] The averages for the 10-year period immediately preceding 1948 show the ratio of 61 to 39. Indiana and Ohio together in 1948 raised within 50,000 as many fall as spring pigs. For the preceding 10 years the ratio was 52.6 to 47.4.

The average monthly distribution of the farrowings in the western and eastern Corn Belt states, respectively, for the 10-year period, 1937 to 1946, is shown in Table 2.[16]

A multiple-litter system of production. A third system of breeding which apparently is being adopted by an increasing number of farmers who specialize highly in commercial pork production is that of farrowing three or more litters a year. The most common program is to breed to have the pigs come as nearly as possible in February, May, and August. When the necessary equipment is adequate and the farm

[15] *Pig Crop Report*, Bu. Agr. Econ., U.S.D.A., June 1, 1949.

[16] North Central Livestock Marketing Research Com., Ia. Exp. Sta. Bul., p. 93, 1948; and Mimeo. Rpt., Bu. Agr. Ec., U.S.D.A., Feb., 1947.

Table 2. Percentage of Sows Farrowing by Months, 1937 to 1946

Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
				Western Corn Belt [a]							
0.9	2.8	13.6	26.7	15.3	6.7	3.5	6.5	13.6	7.5	2.2	0.7
				Eastern Corn Belt [b]							
1.7	5.9	18.7	18.2	8.3	4.1	4.1	9.8	17.2	8.3	2.6	1.1

[a] Western Corn Belt includes Iowa, Kansas, Minnesota, Nebraska, North and South Dakota, and Montana.
[b] Eastern Corn Belt includes Illinois, Indiana, Michigan, Ohio, and Wisconsin.

program well organized and managed, the system produces pork economically. By distributing the production over the year it helps further to solve the seasonal surplus-marketing problem.

The breeder of pedigreed hogs ordinarily finds it to his advantage to breed for early pigs. In addition to the gratification and advertising value of having pigs which are large for the season, they can be disposed of as prospective breeders more promptly and at better prices. The buyer usually favors early purchases, and he is particular in seeking size and growthiness. Pigs intended for show should, of course, come as soon as possible after the critical dates which separate the junior and senior age classes. A new system of classification adopted at most state fairs now provides two classes for spring pigs, senior and junior. Senior spring pigs must be farrowed on or after February 1, and junior spring pigs on or after March 15. Senior or under-year pigs, as a consequence, may be farrowed on or after August 1 of the previous year. February 1 and August 1 in this plan thus replace the dates March 1 and September 1 in the older classification.

HANDLING THE BOAR AND SOWS

The number of sows which the boar can safely breed during a given breeding season will depend on several factors, such as age, natural vigor or fertility, the length of the breeding season, the distribution of the services, his feeding, and the way he is handled. He is considered at his best when 18 months to four years of age. If properly fed and exercised, however, his vigor should be maintained several years longer.

How many sows can the boar breed? Some boars are naturally more vigorous than others and can settle twice the number of sows in a given breeding season. Results will also depend on the judgment and experience of the herdsman. No boar will perform satisfactorily that is constantly mistreated or subjected to frequent abuse, whose services

have not been carefully regulated, that has been confined to a dry lot during the time when not in service, or that is fat and lazy as the result of too much corn and too little exercise.

In addition to the information concerning the effects of frequency of mating on the number and quality of sperms produced by the boar (see Chap. XXI), we have the observation and experience of the practical hogman and breeder. To secure such information the writer interviewed by letter 20 prominent breeders and herdsmen. In practically all cases the breeders replied that the mature boar could breed two sows a day, and occasionally three. One breeder only advised but one service a day, with occasionally two; one breeder said the boar could occasionally breed four sows in one day. It was the experience of practically all these men that the yearling boar is able to take care of as many sows as the mature hog.

In the case of the early spring pig used during the fall season commencing about November 1, it was quite the unanimous expression that he could safely breed one sow a day, and occasionally two. Only two breeders would limit the number of services to as few as three or four a week, and these were men with small herds. Only three of the breeders interviewed reported that they had observed instances where the failure of the boar to settle his sows appeared to be the result of overuse during the previous breeding season.

One of the great hog breeders of the past, N. H. Gentry, says: "Sometimes we use a boar twice a day, and then probably have two or three or four days when we will not use him at all. . . . Sometimes we find ourselves with three or four sows in heat and must use a boar two or three times a day, but not very often. If I use a boar twice in one day, I like to let him miss service afterward for a day or two. I think once a day is doing very well." [17]

The opportunity to "cash in" on the reputation of a boar that has won distinction in the show ring by offering for sale sows bred to him tends to result, especially in the case of the immature pig, in his excessive use. As an example of this abuse there is listed below a number of cases. The number of services was learned by an examination of the matings given in the catalogs for sows offered at auction in bred-sow sales the following January or February.

[17] Quoted by F. D. Coburn in *Swine in America*, Orange Judd Co., 1909, p. 99.

Some sale catalog data.

Boar Number 1—First-prize junior boar pig and junior champion at the National Swine Show. Bred 45 sows in the period from November 6 to December 26; bred 16 sows in one seven-day period.

Boar Number 2—First-prize junior boar pig at the National Swine Show. Bred 59 sows from October 10 to January 12, a period of 92 days; bred 2 sows in one day on six occasions; bred 3 sows in one day on one occasion.

Boar Number 3—First-prize junior boar pig at a state fair. Bred 43 sows from November 6 to January 5, a period of 58 days; bred 2 sows in one day on eight occasions; bred 3 in one day on two occasions.

Boar Number 4—First-prize boar pig at the National Swine Show. Bred 20 sows in November; bred 3 sows in one day on three occasions.

Boar Number 5—First-prize junior boar pig at the National Swine Show. Bred 50 sows which were offered for sale the following winter and spring; the next fall, as a yearling, he was mated with 91 sows.

Bearing in mind the findings of the scientist on the effects of frequent ejaculations on the volume of semen, number of sperms, duration of sperm motility, and number of abnormal or deformed sperms, and giving due consideration to the judgment of breeders in the field based on observation of the results, the following general recommendations appear to be justified: for the pig eight or nine months of age, 15 to 20 sows may be bred during a 30-day season; yearlings and older boars should be capable of taking care of 25 to 45 sows.

Systems of mating. There are two general systems of handling the sows and boars during the mating season. The first, known as hand-coupling, is that of bringing each sow as she comes in heat to the boar; the second is that of allowing the boar to run with the sows a part or all of each day.

The best system to follow will be determined by the conditions. The farmer who has only eight to ten sows to breed finds the practice of turning the boar in with the sows to be satisfactory, as a rule. The chief advantages of this system are that this does not require the individual attention and time of a man when each sow is bred, and secondly, the boar is under conditions which permit plenty of exercise. Also, the chances of missing a sow when she comes in heat are reduced to a minimum in this system. When the number of sows is well within the number which would be safe to breed under these conditions, and

morning before feeding, and the other late in the day, before feeding. The boar should not, of course, be used when full of feed. A double service should be given the sow only when it is apparent that the first was incomplete. If the first service is a satisfactory one, however, an immediate second service should be avoided. If the sow is still in heat 24 hours later, a second service is advisable, provided that it does not endanger the energies of the boar.

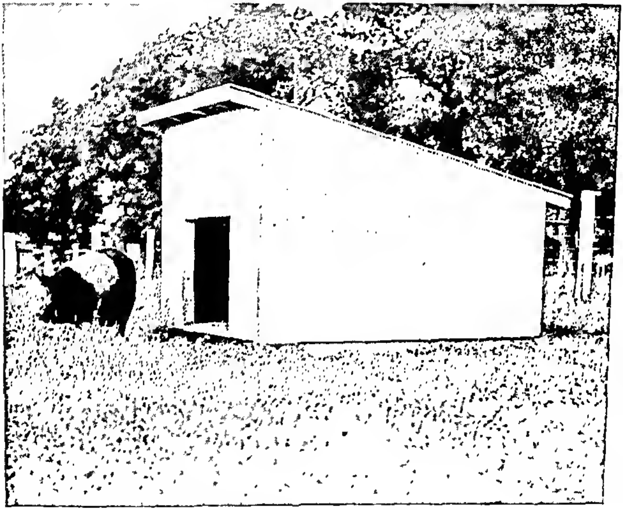


Fig. 6. A very satisfactory type of open-front boar house in use on the Purdue University Farm *(photo by Allen)*

An important fact to remember at this point is that the successful union of the male and female germ cells is dependent on the vigor and activity of the male germ cells (see Chapter XXI). Before reaching the eggs, it is necessary for these cells to travel a considerable distance in the uterus and Fallopian tubes of the sow. This they are able to do by the movement of a tail-like appendage. If the boar is not vigorous, as the result of overuse, or is too fat, or in a run-down condition, experiments indicate that the sperms which he produces will

when it is not considered essential to know the exact date when each sow is bred, there is little in the practice to condemn.

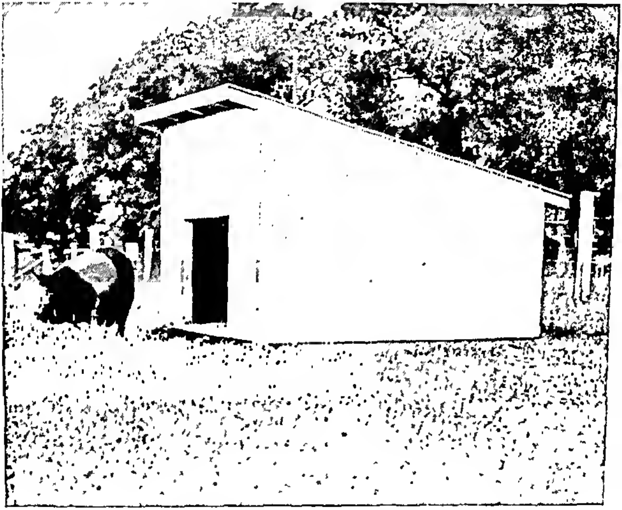
When the number of sows in the herd is larger than this, it is doubtful whether this is the best system, unless there is a surplus of boars of equal merit available. Too often the tendency is to expect the boar to breed as many sows under this system as could be done with safety when the services are regulated by hand-coupling. The results are that the sows are not settled promptly, many of the litters are small, and the ratio of fertile to total services markedly reduced. When running with the sows, the boar should not be expected to breed more than one-half the number which would be safe under the hand-coupling plan.

In pure-bred herds where an accurate record of the breeding of each pig is necessary, any other system than that of bringing the sows to the boar is practically out of the question. In pedigreed herds, the number to be bred is frequently large, also, and several boars are usually in service at the same time, and it is desirable that each sow be bred to a particular boar. The importance of getting each sow successfully bred the first time she comes in heat and the desirability of maintaining the vigor of the boar at a high pitch are so great as to warrant the time and attention required to breed the sows individually under most conditions.

With the opening of the breeding season, the sows should be watched closely for evidences of heat. While, as a rule, a sow in heat is sufficiently demonstrative in her behavior to make detection easy, yet in every herd there are ordinarily a few sows which show few of the usual symptoms. The practice of having the boar and sows in adjacent fields facilitates observation. When in heat, the sow will be found along the fence next the boar and away from the remainder of the herd. From the standpoint of the boar's welfare, however, this arrangement, although productive of exercise, is usually too disquieting to be without serious criticism. This is especially true if the demands on the boar are heavy. The boar in heavy use should be protected from such exciting influences. The practice of having a "teaser," or a boar to which only a few sows are to be bred, in the lot next to the sows is often followed with good results.

Some hints on boar management. When the breeding schedule of the boar is a heavy one, every effort should be made to time the services so that a reasonable interval shall intervene between them. When two sows are in heat at the same time, one should be bred in the

morning before feeding, and the other late in the day, before feeding. The boar should not, of course, be used when full of feed. A double service should be given the sow only when it is apparent that the first was incomplete. If the first service is a satisfactory one, however, an immediate second service should be avoided. If the sow is still in heat 24 hours later, a second service is advisable, provided that it does not endanger the energies of the boar.



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lack vigor and activity. Such germs will be short-lived and sluggish, and the chances that each egg produced will be fertilized by a vigorous sperm will be greatly reduced.

The condition or breeding capacity of the boar will be largely influenced by his exercise and feeding during the weeks preceding the opening of the breeding season. No amount of attention to these matters after the season has begun will compensate for a lack of attention to them earlier. It is the opinion of many experienced handlers also that the failure of the boar to settle his sows promptly is, in some instances, the result of too infrequent services, or to a long period of enforced idleness. Because he seems less sure at the beginning of the breeding season, it is a good plan to start him a week early on a few sows or gilts that are soon to be marketed, when these are available. Young boars of unknown fertility, especially those which have been transported long distances, should be tried out on a few market gilts before the regular breeding season opens.

Patience and good judgment in handling the boar are necessary for best results. When the sow is turned in, he should be allowed to take his own time preliminary to mounting. The fussy impatience of the herdsman often proves to be a distracting annoyance, which interferes seriously with those necessary reactions on the part of the boar that are prerequisite to breeding. If he has any peculiarities or idiosyncrasies as regards the conditions which he requires, they should be recognized and catered to. So far as possible, a regular schedule as to time and method of bringing the sows and boar together should be observed. After she has been bred, the sow should be placed in a pen by herself until heat has passed.

The owner of the great boar Masterpiece, A. J. Lovejoy, said: "Every time he is used he walks forty rods from his home to the breeding house. The sow is taken from her mates the night before and put in a crate where she can't see other hogs. In the morning, before breakfast, the herdsman walks the boar down to the breeding house and lets him lie there until after breakfast. Then he uses him and immediately puts the sow in a dark, quiet place until she goes out of heat. He lets the boar lie for half an hour and then walks him home." [18]

The breeding crate. When a mature heavy boar is to be bred to gilts, or the boar pig to mature rangy sows, a breeding crate is practically a necessity. Some breeders prefer its use even though the boar and sows are of the same size and type. They claim that a satisfactory

[18] Quoted by F. D. Coburn, *Swine in America*, Orange Judd Co., 1909, p. 100.

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service is more certain with than without it, and that its use proves less wearing on the energies of the boar. The boar, however, has to be taught to use it and with some individuals considerable patient effort is necessary before this is accomplished. Those that have formed the habit of breeding under natural conditions are especially backward, while some refuse altogether. For breeding gilts to a heavy hog, an improvised crate can be made by placing the gilt between two bales of straw, with one in front.

Farmers, as a rule, do not favor the breeding crate chiefly because of the time and individual attention required and also because they have had no experience in observing its use. The unpopularity of mature boars for use in commercial herds is the result of this objection. Some think the sow more likely to miss conception when bred under such artificial conditions. There is no reliable evidence, however, that the proper use of the breeding crate will interfere in any way with fertility.

H. R. Davidson in his excellent book, *The Production and Marketing of Pigs,*[19] offers some good advice for handling young boars temporarily suffering from what he calls psychological frustration. He says:

> A small boar making his first service may be used on a sow or older gilt which is much too large for him, or on a gilt that will not stand still. After many efforts and considerable exhaustion he gives up in despair. Often the effect is to produce a conditioned reflex which leads to his refusal to try at the next opportunity.—I have cured one complete and several partial cases of this condition by appropriate treatment, but that is not to say that the condition is always amenable to treatment. The boars were removed from all contact with sows or gilts in heat, heavily purged with salts and then put on a very light ration till they lost some condition. After some weeks, during which time they were allowed ample exercise on pasture, sometimes with in-pig sows, and when they had become active, keen and on good terms with their associates, they were introduced suddenly to a gilt of just the right size, fully in heat and known to be of sensible disposition.

Records. The breeder of market hogs does not, as a rule, make a record of the date each sow is served. When the sows are bred early and the farrowing season is in February or March, however, a knowledge of the time each sow is due will make possible that preparation and individual attention at farrowing time which are necessary to save the pigs in cold weather. Without a knowledge of the date of service, it will be necessary to depend on careful observation and judgment to indicate when the sows are due. Even with the most care-

[19] Longmans, Green & Co., London, 1946, p. 406.

ful supervision, the experienced hog raiser makes many bad guesses, and as a consequence a number of the sows farrow with the general herd and under conditions not favorable to the survival of the pigs. Such experiences suggest that it might be practical for the producer of market hogs, especially when early pigs are attempted, to have his sows tagged and a record made of the time of breeding. There is also another advantage. If the sows are tagged and their litters ear-notched, information will be available later regarding the number and quality of pigs weaned and marketed from each sow, a record of production which is necessary in order to know which to retain and which to discard for the next breeding season.

With pure-bred herds, breeding records are a practical necessity. When more than one boar is in service, as commonly is the case, the record must be depended on in writing the pedigrees of the pigs later, as well as to indicate when each sow is due to farrow. Before the breeding season begins, the boar to which each sow is to be bred should be determined as far as possible. Each sow must wear an ear tag bearing her number, a breeding sheet should be made out containing the name or number of each sow, the name of the boar which it is proposed to breed her to, with spaces for recording the date of service. The knowledge of the sire and dam of each sow is important, also, to guard against the possible use of a too closely related sire. If this sheet is posted in some convenient place in the hog barn, the entries can be made promptly. With the close of the breeding season, the date of service and the name of the boar bred to should be transferred to the permanent record.

The following record form embodying these features has proved practical and convenient to use.

Breeding Record—Fall, 1950

Name or Number of Sow	*Sire and Dam*	*Boar Bred to and Dates of Services*	*Remarks*

FEEDING THE SOWS

In order that the sows may be at the maximum of breeding thrift, it is necessary that special attention be given their feeding and care several weeks before mating. Mature sows which are thin in the fall as the result of plenty of grass and exercise and little or no grain are in ideal condition for this preliminary treatment. Sows which have weaned fall litters also are in good condition to respond favorably.

Sows should be flushed. This treatment, known among shepherds as "flushing," consists in feeding the sows so as to cause them to gain from three-quarters to a pound daily a week before the opening of the breeding season and until they are safely in pig. The practical effect of such feeding seems to be to stimulate all the vital functions, and among them the breeding function, to greater activity. When it is remembered that the size of the litter is limited by the number of eggs produced by the sow, the importance of such a condition is magnified. It has also been observed that sows when gaining in flesh and thrift tend to come in heat promptly and to be more susceptible to impregnation when bred.

To respond favorably to the treatment suggested above, the sows must be thin in condition at the beginning. Sows that are already as heavy as is consistent with vigor and activity should be stimulated, if possible, by supplying plenty of range and exercise with access to green feed. With show sows or those very high in condition, it is usually necessary to reduce in flesh before they will breed. This should be done without subjecting them to any sudden change in diet, by withdrawing the grain from their rations gradually, and by stimulating exercise by allowing them the freedom of a good pasture. To establish regular breeding habits in a sow that has been highly fitted is as reliable a test of good feeding as is the ability to bring her up to the bloom of show condition.

To ensure successful reproduction, it is particularly necessary that the gilt be fed during the pregestation or growth period a ration that is complete in all nutritional essentials. Cunha of the Washington Station and Fairbanks of the Illinois Station [20] demonstrated the effectiveness of fine-quality alfalfa for correcting the deficiency of many so-called good rations. At Illinois, the addition of 12 percent of high-quality alfalfa meal to an otherwise good ration of yellow corn, soybean oil meal, fish meal, tankage, limestone, bone meal, salt, and fortified cod

[20] Reported by Damon Catron, *Hog Breeder*, March, 1949.

but it must be properly balanced. A complete ration requires, in addition to corn or other cereal, one or more protein-rich supplements (preferably partly of animal origin), a good salt or mineral mixture, and green feed.

Some boar rations. Below is listed a few rations which represent nearly ideal combinations, by weight, for the boar during the breeding season.

Ration 1

40% ground corn
29% finely ground or rolled oats
20% wheat shorts or middlings
10% high-grade protein supplement, partly animal origin
1% simple mineral mixture (equal parts limestone, special steam bone meal, and salt)
Green forage

Ration 2

45% ground corn
28% finely ground oats
20% red dog flour
5% alfalfa leaf meal
2% simple mineral mixture
2 to 3 gallons skim milk or buttermilk, daily

Ration 3

35% ground barley
25% finely ground or rolled oats
20% wheat shorts or middlings
8% linseed or soybean oilmeal
5% tankage, meat meal, or fish meal
5% alfalfa leaf meal
2% simple mineral mixture

Ration 4

30% ground corn
25% cracked wheat
23% ground oats
5% wheat bran
5% alfalfa leaf meal
10% high-grade protein supplement
2% mineral mixture

Ration 5

30% ground corn
30% cracked wheat
20% ground oats
5% wheat bran
14% high-grade protein supplement
1% mineral mixture
Green feed, ad. lib.

Ration 6

39% ground wheat
30% ground oats
15% green alfalfa meal or leaf meal
5% wheat bran
5% meat and bone scrap, or tankage, or fish meal
5% soybean or linseed oil meal
1% simple mineral mixture

The above rations are abundantly rich in proteins, minerals, and vitamins, the food constituents that most directly affect fertility. They are especially recommended for boars doing heavy service. Ration No. 5 is designed especially for the boar pig, and No. 6 for the over-fat mature boar. A suitable mineral mixture is made up of equal parts of limestone dust, special steam bone meal, and iodized salt. It may be fed as suggested, or self-fed. When the latter method is employed, the

combination of limestone and bone meal may be fed in one compartment of the feeder, and the salt in the second compartment.

Most breeders believe they can maintain the proper condition of the boar better by hand than by self-feeding. They also favor feeding most of the ration in the form of a thick slop rather than dry. This, however, is not a vital matter. The amount fed should be regulated so that there will be no excess or deficit in the supply. Close observation of the condition of the boar, with good judgment, are the best guides. Full rations will, of course, be necessary when the schedule is a full one. Even with the most liberal feeding the mature boar usually will lose weight when used heavily.

Special treatment for sluggish boars. Occasionally the boar will "go off his feed." In such a situation special treatment may be advisable. A number of hogmen have testified to the value of eggs fed as part of the regular ration in helping to bring him through a particularly heavy season. Attention in such cases should also be given to his likes and dislikes by supplying for a time the feeds most appealing to his palate, even though it may mean, temporarily, a lack of balance in the ration. As a general practice, the feeding of special tonics or drugs is to be condemned. For the normal well-conditioned boar, they will do more harm than good.

To stimulate vigor in boars that have temporarily lost all sex interest, the result in many instances of too long a period of idleness and high condition, the feeding of one gram daily of thyroprotein (iodinated casein) has been favorably reported on.[21] The use of thyroprotein or gonadotropic hormones in the treatment of the various types of impotency or sterility, however, it should be emphasized, is strictly in the early experimental stages of development.

The feeding of wheat-germ oil, a rich source of the antisterility vitamin E, has been favorably reported on by a considerable number of breeders as a means of stimulating sex interest in sluggish or indifferent boars at the start of the breeding season. This vitamin, which is necessary for reproduction, however, is present in large amounts in natural feeds. Grains and seeds, where it is concentrated in the germ, green forage, and the leafy part of good-quality hays, are rich in it. The author has found no experimental evidence that it is of any value when normal good rations are fed. Well-constructed rations apparently supply an abundance of this vitamin.

[21] Andrews, F. N., *Jr. Am. Vet. Med. Ass'n*, Vol. CX, No. 842, May, 1947.

III Feeding Pregnant Sows and Gilts

There are two principal points which should be kept in mind when feeding sows during the gestation period. These are, first, to provide a ration which will ensure the complete nourishment of the sow and her developing litter, and, second, to choose the feeds and adopt a method of feeding which will prove economical and adaptable to the farm conditions.

NUTRITIONAL NEEDS OF THE PREGNANT SOW

Why good rations are necessary. The nourishment of the sow during the gestation period affects her performance subsequently in a variety of important ways. It affects the number, strength, and weight of the pigs farrowed, the number born dead, and the number and weight of the surviving pigs at weaning time. It is a factor in the general health and vigor of the sow and her ability to give birth to her pigs without difficulty or complications, the promptness of her recovery, her ability to initiate milk secretion, and her capacity for sustained lactation during the all-important nursing period. Other factors, of course, such as heredity, care and sanitation, and exercise, also are involved to a greater or lesser degree in affecting these results. At this time, however, we are concerned with the nutrition side alone.

Good feeding also requires that the ration be cheap as well as complete and balanced. The cost of feeding the sow during this period is an important item in the feed cost of the individual pigs at birth; and this represents a considerable part of the cost of the finished market pig (see Chap. XVI).

There are a number of important facts relating to reproduction with which all hogmen should be familiar in order to appreciate better the extent and nature of the food demands of the pregnant sow. Because of their significance they are in the real sense key facts.

Loss of weight during farrowing and nursing. The first of these has reference to the loss of weight which occurs when the sow gives birth to her litter. Vestal of the Indiana Station [1] reports this loss for 445 sows and 248 gilts fed various types of experimental rations over a period of 15 years, from 1921 to 1935. For the mature sows the averages for the different years varied from 30 to 44 pounds with a general average of 38 pounds. The loss for the gilts ranged from 20 to 37 pounds with a general average of 27 pounds. Records of individual sows in the Purdue University herd over a period of four years showed a loss varying between 25 and 55 pounds for mature sows. For these sows this loss of weight was distributed as follows: 29 pounds, in round numbers, in the pigs themselves, 5 pounds in the placental

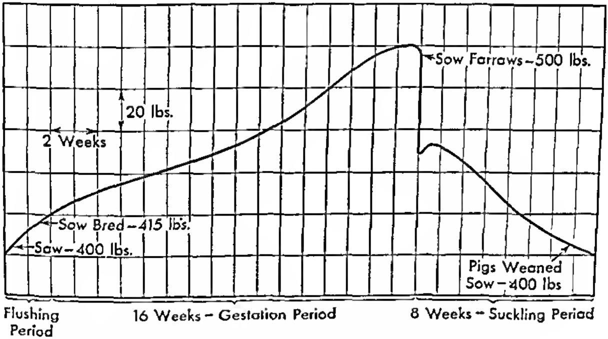

Fig. 7. Curve showing the typical fluctuations which normally occur in the weight of the mature sow during one reproduction cycle.

membranes or afterbirth, and 11 pounds in the amniotic fluids and products of metabolism, representing a total average loss of 45 pounds.

Considering this loss along with that which normally occurs during the lactation period, it is clear that if the mature sow is to be approximately of the same weight when she weans her pigs as she was when bred, she must be fed sufficiently liberally during pregnancy that a gain of 75 to 100 pounds is assured. Young sows and gilts carrying their first litters should gain at least this much for, in addition

[1] C. M. Vestal, Bul. 413, March, 1938.

to the above losses in kind, provision should be made for the normal growth of the gilt herself.

Protein and mineral needs. Equally important with the extent or volume of the loss of weight at farrowing time is its nature or composition. A gross examination of the carcass of the new-born pig reveals that it is made up mostly of muscles and similar tissues, internal organs, bones, fat, and skin. On the dry-matter basis this material, as shown by chemical analysis, is composed of 70 percent protein or nitrogenous material, 20 percent ash or mineral matter, and 10 percent fat (see Table 3). The other products of growth during pregnancy are represented by the placental membranes, the mammary glands, and the increase which occurs in the size of the uterus. The latter, however, is not lost at farrowing time; it remains and on its partial absorption may serve as food for the support of lactation. These tissues are even more nitrogenous in nature than those of the new-born pig.

Food requirements increase with advancing pregnancy. More exact information about the products of pregnancy is furnished by the fundamental studies of Mitchell and associates at the Illinois Station.[2] Detailed chemical analyses were made of the uteri and contents of 16 pregnant gilts, the litters averaging eight pigs, at different stages in the gestation period. The first gilt studied was killed at the end of the fifth week of pregnancy; at the end of each of the subsequent weeks, up to and including the sixteenth, one or two gilts were slaughtered and the products of reproduction analyzed. The detailed figures given in Table 3, based on these determinations, show the daily rate of deposition of the principal food constituents.

Some interesting facts are revealed by a study of these figures. It is to be observed, for example, that more than two-thirds of the growth was made during the last four weeks of the gestation period; in all the constituents there was a progressive increase in the rate of deposition. This was particularly true of calcium (lime). At the close of the sixteenth week of pregnancy the nutrients were being deposited at more than double the rate than at the termination of the tenth week. Other figures in these studies showed that the uterus reached its maximum development in the twelfth week, at which time it was 16 times the size of the nonpregnant uterus. At the end of nine weeks the placental membranes had reached full development and the amniotic fluid was at its maximum at the end of eight weeks. The amount of iron found

[2] H. H. Mitchell, W. E. Carroll, T. S. Hamilton, and G. E. Hunt, *Food Requirements of Pregnancy in Swine*, Bul. 375, 1931.

Table 3. Computed Daily Rate of Increase in Weight and Energy Content, and Computed Daily Deposition of Nutrients in the Uteri of Pregnant Gilts (Ill. Exp. Sta.)

Week of Gestation	*Total Weight* [a]	*Crude Protein*	*Gross Energy*	*Ash*	*Calcium*	*Phosphorus*	*Iron*
	gms.	gms.	cals.	gms.	gms.	gms.	mgms.
1	27	0.54	1.6	0.028	0.0001	0.0011	0.28
2	49	1.5	5.9	0.126	0.0018	0.0074	0.71
3	71	2.7	12.5	0.30	0.0081	0.022	1.24
4	91	4.2	21	0.57	0.024	0.048	1.84
5	111	5.9	32	0.93	0.055	0.087	2.50
6	131	7.7	45	1.38	0.109	0.142	3.2
7	150	9.6	59	1.93	0.194	0.215	4.0
8	169	11.8	76	2.6	0.32	0.31	4.8
9	187	14	94	3.3	0.50	0.42	5.6
10	205	16	115	4.3	0.74	0.56	6.5
11	224	19	137	5.2	1.05	0.72	7.4
12	242	21	160	6.2	1.46	0.91	8.3
13	259	24	186	7.4	1.97	1.13	9.2
14	277	27	213	8.7	2.60	1.38	10.2
15	294	30	242	10.1	3.37	1.67	11.2
16	312	33	272	11.7	4.29	1.98	12.3

[a] One ounce = 28.35 grams; one pound = 453.6 grams.

in the liver and spleen was greater than that contained in the entire body outside these organs, although it did not exceed published figures for mature pigs.

Although the progressive increase in the rate of development of the foetus and related organs during gestation indicates the need for an increasing daily food supply as pregnancy advances, it should, at the same time, be recognized that heavy feeding during the last weeks of pregnancy, as well as scanty rations during the weeks immediately following breeding, should be avoided. Davidson [3] expressed the view, based on extensive observation, that high feeding during the last few weeks of pregnancy is one of the main causes of flushed overstocked udders and resulting congestion. He reports success with the plan of feeding the sow up at once after breeding to the condition desired at *farrowing time*.

That good nutrition should be provided during the critical two or three weeks immediately following breeding is suggested by the fact that it is during this time that implantation of the fertilized eggs is tak-

[3] H. R. Davidson, *The Production and Marketing of Pigs*. Longmans, Green & Co., London, 1948, p. 414.

ing place. McKenzie of the Missouri Station[4] found a close relationship between the gains made during the four weeks following breeding and the number of pigs farrowed. Investigations generally have shown that, in a group, those sows that gain most during gestation farrow the larger litters.

Maintenance needs must be provided. In addition to supplying the materials needed to grow the foetal litter and associated parts, the ration of the pregnant sow should provide food for maintenance, *i.e.*, for the nourishment and upkeep of her own body. The requirements for maintenance are foods chiefly of a carbonaceous nature, which supply energy and heat to run the body machine and maintain its temperature. In addition, a small but constant amount of protein and mineral matter is required to repair the daily body wastes. Unlike the demands for the support of embryonic growth, the maintenance needs may be met by rations which are preponderantly carbonaceous in character. In the former case also the food demands are limited chiefly to the last half of the gestation period, while the demands for maintenance, assuming uniform weather conditions, are constant.

With the gilt carrying her first litter, there is needed, in addition to food for maintenance, material which will provide for the continuation of her own growth and development. A somewhat larger supply of protein and mineral matter than is necessary in the ration of the mature sow is therefore desirable, particularly during the first half of the pregnancy period.

Food reserves of body should be built up. A third very important point is the desirability of building up in the body of the sow a food reserve which will be available later to supplement the rations during lactation. This reserve is valuable because normally the demands for milk production are greater than can be supplied by the rations fed at the time. The requirements for milk production, in other words, may exceed the capacity to digest and assimilate food. This is especially true if the sow is a heavy milker. If the sow arrives at farrowing time in thin condition, especially if her ration during pregnancy has been deficient in protein, calcium, or vitamins, as is not uncommon, her limited food reserves will be exhausted early and a failure in the milk supply will result. In more extreme cases, a complete breakdown may occur. The tendency of the sow to take on weight during the pregnancy period, that is, to accumulate food reserves, is a natural one and should be encouraged to the extent that at farrowing time she may

[4] F. F. McKenzie, Res. Bul. 118, 1948.

be in what the breeder describes as a strong but active breeding condition.

SOME EXPERIMENTAL STUDIES

As a result of the varied nature of the food demands of the pregnant sow and the tendency or temptation of the average feeder to depend too exclusively on corn or other cereals in feeding her during the winter, the problem of supplying suitable rations which are adequate in all essentials is one of considerable practical importance. Particularly in the Corn Belt the ration is likely to be deficient in protein and mineral matter, especially calcium. When white corn, or any cereal other than yellow corn, is fed the supply of vitamin A also becomes a factor requiring attention. Other vitamins, such as the antirachitic vitamin D and the numerous factors contained in the B complex group of vitamins, have been given special significance by recent studies because of their relation to baby pig losses and the maintenance of a high level of production.

It will be our purpose now to consider some of the experimental studies which demonstrate the deficiencies of corn and other grains, and their need for protein, mineral, and vitamin supplements.

Corn alone not suitable for yearling pregnant sows. Experiments conducted by Evvard of the Iowa Station,[5] begun in 1910, were among the first to demonstrate clearly the fact that young sows are unable to produce strong pigs when fed during the gestation period on corn alone. In one trial 30 yearling sows were divided equally into three lots at breeding time and fed the following rations up to the time of farrowing: Lot I, corn alone; Lot II, corn and tankage; and Lot III, corn and linseed oil meal. The amount fed was regulated in each lot by the condition and weight of the sows. All groups had access to open lots and were under identical conditions as regards exercise and shelter. The results, as expressed in the weight and strength of the pigs at birth, are shown in Table 4.

The sows which received either tankage or linseed oil meal with corn produced heavier and stronger pigs than did those which were restricted to corn alone. That this should be the case occasions no surprise among experienced feeders. The differences were sufficiently marked to be significant. The real importance of them, however, lies in the fact that weak pigs are likely to suffer heavy mortality during the first few weeks of life. A report on the number and weight of these pigs

[5] John M. Evvard, *Proc. Am. Soc. An. Prod.*, Dec., 1913.

Table 4. Corn Alone versus Corn and a Protein Supplement for Pregnant Yearling Sows

Average Daily Ration	*4.97 Lb. Corn*	*4.11 Lb. Corn 0.50 Lb. Tankage*	*4.06 Lb. Corn 1.13 Lb. Linseed Oil Meal*
Average daily gain, each sow	0.59 lb.	0.78 lb.	0.67 lb.
Average number pigs farrowed, each litter	9.2	10.1	8.8
Average birth weight, pigs	1.85 lb.	2.42 lb.	2.22 lb.
Average birtb weigbt, litters	17.02 lb.	24.44 lb.	19.54 lb.
Vigor of pigs:			
Strong	41%	85%	76%
Medium	35%	5%	15%
Weak	20%	5%	5%
Dead	4%	5%	4%

at weaning time probably would have revealed greater differences still.

Pregnant sows cannot produce strong pigs and be in condition to nourish them successfully when restricted to a diet of corn alone. Corn is a fattening feed; it does not contain enough of those food materials which make muscle and bone, that is, protein and minerals. The sows fed corn alone received daily but little more than one-half as much protein from their ration as those fed either tankage or linseed oil meal in addition. To get the amount of protein sufficient to meet her needs, it would be necessary for a sow limited to corn alone to eat such a large amount that her ability to farrow and raise her pigs would be seriously jeopardized by excessive fatness. The quality of the proteins of corn also is such that a given amount is less efficient in meeting the needs of the pregnant sow than the same quantity coming from a combination of corn and a protein supplement.

Another serious deficiency was the meager supply of calcium, as well as some other essential minerals. This was one of the chief causes responsible for the lack of strength and development of the pigs at birth. The corn-alone ration contained but 0.02 percent of calcium, the corn-tankage ration 0.63 percent, and the corn-linseed ration 0.09 percent. Only in the tankage ration was the supply sufficient. Some of the vitamins, especially those belonging to the B complex group, were also lacking. The explanation of why more serious consequences did not follow in the case of the sows fed corn alone, as well as in the case of those in the other two lots, is that the open lot afforded them the opportunity to supplement their mineral supply from the soil, and their state of nutrition at the beginning of the trial must have been such

as to ensure liberal body reserves of protein, minerals, and vitamins.

These observations concerning the nutritional defects of corn, when judged as a sole feed, apply with little modification to the other cereal grains, wheat, oats, barley, rye, and the grain sorghums.

Bred gilts require a protein supplement. In Table 5 are summarized the results of experiments conducted by Vestal of the Indiana Station in 1927 and 1928, and Evvard of the Iowa Station,[6] in which a ration of grain alone was compared with grain supplemented with tankage for bred gilts during the winter. In the Indiana trials the grain was composed of two parts shelled corn and one part whole oats, by weight, and in the Iowa trials ear corn alone. The experimental rations were fed from the beginning of the breeding season until farrowing time. There were all together 51 sows involved in the tests. Opportunity to exercise at will was ensured in each experiment by giving the sows the liberty of open lots.

Table 5. Grain Alone versus Grain and Tankage for Pregnant Gilts
(Average 4 Experiments)

Daily Ration	*4.36 Lb. Grain*	*3.81 Lb. Grain 0.25 Lb. Tankage*
Feed fed daily per hundredweight of sow	1.76 lb.	1.59 lb.
Daily gain, each gilt	0.476 lb.	0.594 lb.
Number pigs farrowed, each litter	7.74	7.81
Birth weight, pigs	2.11 lb.	2.34 lb.
Vigor of pigs:		
Strong	62%	86%
Medium	24%	10%
Weak	10%	2%
Dead	4%	2%

As was the case with the yearling sows, in each of the trials here reported the gilts which received a small allowance of tankage produced the heavier and stronger pigs. Also, they consumed less feed and made more gain during the period. In neither of the lots, however, were the results wholly satisfactory.

That the weight and strength of pigs at birth are related to their ability to survive and thrive later was shown in the Indiana trials, which were continued to include the nursing period. During this time the sows of both lots were fed a good milk-producing ration composed of eight parts corn, two parts shorts, and one part tankage, with access to rye pasture. The sows which had received the tankage during the

[6] John M. Evvard, *Proc. Am. Soc. An. Prod.*, Dec., 1913.

gestation period raised 82 percent of their pigs, the litters averaged 136 pounds at weaning time, and the individual pigs 22 pounds; the sows which had only corn and oats raised 75 percent of their pigs, the litters averaged 101 pounds when weaned, and the individual pigs 17 pounds.

Corn and oats with and without tankage. From 1921 to 1928 Vestal of the Indiana Station fed one group of mature sows during the winter gestation period a ration composed of two parts shelled corn and one part whole oats, and to another comparable group the same with 5 percent of tankage added. There were a total of 32 sows which received the grain without the supplement, and 28 in the lot which received tankage in addition to the grain. The amount fed was limited so that the sows in both groups would be in medium condition at farrowing time. Liberal exercise was encouraged in both lots by locating the houses at the far end of dirt lots which were about 100 yards deep. A summary of the results, representing averages based on the individual sow, is shown in Table 6.

Table 6. Adding Tankage to a Corn and Oats Ration for Mature Pregnant Sows

Rations	*Shelled Corn ⅔, Whole Oats ⅓*	*Shelled Corn ⅔, Whole Oats ⅓, + 5% Tankage*
Initial weight of sows	389 lb.	399 lb.
Feed fed daily per hundredweight	1.40 lb.	1.34 lb.
Total gain each sow during gestation period	53 lb.	59 lb.
Number pigs farrowed per litter	9.03	10.13
Birth weight of pigs	2.62 lb.	2.62 lb.
Vigor of pigs:		
Strong	71%	68%
Medium	17%	18%
Weak	7%	8%
Dead	5%	8%
Number of pigs raised	73%	69%
Weight lost per sow during nursing period	35 lb.	44 lb.
Litter weight at weaning	165 lb.	172 lb.

Although the sows which received the tankage gained slightly more on less feed during the gestation period, those which were fed corn and oats only produced pigs which at birth were equal in weight and vigor to those in the other lot. The results in all important respects were

practically the same. So far as any effect which the rations may have had subsequently during the suckling period, also, there does not appear to have been any difference. The number and weight of the pigs at weaning time were very nearly the same. Both groups of sows during the nursing period were on rye or timothy pasture and were fed a milk-producing ration composed of eight parts corn, two parts wheat shorts, and one part tankage, with minerals.

Results obtained by Carroll of the Illinois Station [7] with similar rations agree in general with those just reviewed. During one winter gestation period in this experiment seven sows were fed a ration composed of nearly equal parts ear corn and oats, with a mineral mixture; a second comparable group of six sows was fed the same ration except that each sow was given in addition about one-third pound of tankage daily. So far as could be judged by the weight and strength of the pigs at birth there was no evidence that the addition of the tankage was advantageous.

That the sows fed corn and oats alone during gestation were able to produce strong pigs despite a deficiency in the supply of good-quality proteins and minerals, especially of calcium and salt, and vitamins, must be attributed to the liberal rations and legume forage which were supplied to them during the preceding summer and fall, and to the improved rations fed during the lactation period. Also it should be noted that the sows were in dirt lots, had liberal exercise, were exposed to sunlight, and were in medium condition of flesh when they farrowed (see page 46).

Corn and oats compared when properly supplemented. Oats are more bulky and less fattening than corn and consequently are generally regarded as a safer feed for mature sows during the gestation period, especially when not fed with a protein concentrate. Experiments by Carroll of the Illinois Station [8] covering two winters and involving the use of 52 two-year-old sows, failed to show any important difference, however, when they were fed with fine-quality alfalfa hay and a good mineral mixture. In these trials the hay was fed in the long condition in racks. The mineral mixture, which was self-fed, was made up of two parts ground limestone, two parts deodorized bone meal, and one part salt. The results, which are shown in Table 7, represent the average for the two experiments.

In neither of the two experiments was there a significant difference

[7] W. E. Carroll, A. H. Mimeo. 314, 1935.
[8] W. E. Carroll, A. H. 314, 1935.

in the results so far as shown in the weight and condition of the pigs at farrowing time. It is to be noted that nearly a pound more of oats than of corn was fed daily. The large consumption of hay in both lots is to be regarded as an important factor in the results secured.

Table 7. Corn versus Oats, with Alfalfa and Minerals, for Mature Sows

Daily Rations	*G. or S. Corn 5.37 Lb., Alfalfa 1.45 Lb., Minerals 0.05 Lb.*	*G. Oats 6.32 Lb., Alfalfa 1.41 Lb., Minerals 0.06 Lb.*
Initial weight of sows	450 lb.	449 lb.
Feed fed daily per hundredweight	1.41 lb.	1.69 lb.
Total gain each sow during gestation	76 lb.	85 lb.
Number pigs farrowed per litter	10.65	9.90
Birth weight of pigs	2.76 lb.	2.80 lb.
Vigor of pigs:		
Strong	60%	62%
Medium	15%	10%
Weak	15%	10%
Dead	10%	18%

In another experiment, Carroll [9] compared shelled corn with ground oats for pregnant sows during the summer on blue-grass pasture. Because of drought, however, the pastures furnished little feed after July 1. Each lot of 15 sows had a 2½ acre field. A standard mineral mixture was self-fed in both lots and an amount consumed equivalent to about 2½ percent of the ration. Those getting corn received 0.75 pound daily per hundredweight, and those getting oats 0.82 pound. Both lots of sows made the same daily gain in weight, which averaged 0.36 pound. Although the pigs from the sows which were fed oats were slightly heavier at birth—2.77 against 2.69 lb.—the pigs from the corn-fed sows had a slight advantage in vigor.

The same investigator also compared ear corn with a combination of ear corn and whole oats, about equal parts of grain by weight, for 2-year-old winter-pregnant sows numbering 13 in each lot. Both rations included a small amount of tankage, 0.29 and 0.28 pound, respectively, for each sow daily, alfalfa hay supplied in racks (of which they ate little), and a good mineral mixture. The results at farrowing time, as shown by the number, size, and strength of the pigs, were such as to warrant the conclusion that the rations were equally satisfactory.

[9] W. E. Carroll. A. H. 314. 1935.

Alfalfa hay demonstrates its value. The early experimental studies of Snyder of the Nebraska Station [10] demonstrated the practical value of alfalfa hay for the winter feeding of bred sows and gilts in reducing feed costs and promoting thrift. His results, together with those of similar later studies by other investigators, have suggested the probable presence in fine-quality leafy alfalfa of unidentified food factors of high nutritional value. In each of five winters he fed an average of 24 bred gilts one part of chopped alfalfa hay mixed with two to three parts of grain. As much of this mixture was fed as the gilts would clean up, which method was equivalent, in effect, to self-feeding. When the gilts showed evidence of becoming too fat, the proportion of grain was reduced and the alfalfa increased. The interesting details of this plan of feeding, and the average results, are shown in Table 8. The figures for the individual years are, of course, not comparable with one another.

Table 8. Wintering Bred Gilts on Grain and Chopped Alfalfa Hay

Rations Fed	*Corn, Barley, Chopped Alfalfa Hay, 1909–10*	*Corn, Barley, Rye, Wheat, Chopped Alfalfa Hay, 1910–11*	*Corn, Chopped Alfalfa Hay, 1911–12*	*Corn, Chopped Alfalfa Hay, 1912–13*	*Wheat, Chopped Alfalfa Hay, Alfalfa Hay in Rack, 1913–14*	*Average 5 Years*
Pounds of grain fed daily per hundredweight gilt	1.90	1.52	1.75	1.90	1.90	1.79
Pounds of grain fed daily per gilt	4.12	3.98	4.07	4.69	4.61	4.29
Pounds of alfalfa fed daily each gilt	1.28	2.01	1.64	1.60	1.66	1.64
Weight of gilts beginning of experiment, lb.	156	201	188	181	166	178
Daily gain each gilt, lb.	0.96	0.97	0.71	0.88	1.08	0.92

The system of feeding followed in these demonstrations ensured large gains and the gilts were in rather heavy flesh at farrowing time. From the standpoint both of feed economy and the number and quality of the pigs produced, the results were reported as satisfactory in all years. Rather large litters of vigorous pigs were produced and no trouble occurred at farrowing time.

[10] W. P. Snyder, Bul. 147, 1915.

Alfalfa hay alone for wintering mature sows. The possibility of wintering mature pregnant sows on alfalfa hay without grain was studied in three experiments by Snyder of the North Platte, Nebraska, Station [11] and in two by Grimes and Havner of the Pennsylvania Station.[12] In each of the five trials one group of five sows was fed alfalfa hay in an open rack with shelled or ear corn in addition. The amount of corn fed was limited to one pound daily for each hundredweight of sow. The amount of the rations consumed and the results, so far as they affected the number and weight of the pigs farrowed, are summarized in Table 9.

Table 9. Alfalfa Hay Alone for Pregnant Mature Sows
(Average 5 Experiments)

Rations	*Alfalfa Hay in Rack*	*Alfalfa Hay in Rack + 1% Corn*
Number of sows	25	25
Daily consumption of alfalfa	5.15 lb.	2.30 lb.
Daily consumption of corn		4.05 lb.
Initial weight of sows	341 lb.	336 lb.
Weight of sows just before farrowing	321 lb.	376 lb.
Gain during gestation period	−20 lb.	40 lb.
Number pigs farrowed per litter	8.15	8.30
Birth weight of pigs	2.29 lb.	2.46 lb.

The results from the individual experiments quite uniformly agreed with the averages as given in the table. The first item of interest is the figure showing that the sows which received no grain consumed, on the average, 5.15 pounds of alfalfa hay daily. The largest amount eaten in any experiment was 5.78 pounds and the smallest 4.03 pounds. As a result of its high fiber and low energy content, however, there were not sufficient nutrients available to maintain the weight of the sows, which lost 20 pounds each during the gestation period. Those getting corn in addition to alfalfa gained 40 pounds each. The consumption of hay in this lot ranged from 1.49 to 2.99 pounds daily. Although the hay consumed by the sows on alfalfa alone furnished practically as much protein and more lime than the corn-alfalfa ration, the total digestible nutrients contained amounted to but little more than one-half that supplied in the latter. The pigs produced by the sows which received alfalfa alone were light in weight but strong, and Snyder

[11] W. P. Snyder, Bul. 162, 1917.
[12] M. F. Grimes and H. H. Havner, Bul. 168, 1921.

reported that the sows raised their pigs as well as those that had been fed corn in addition.

The results clearly indicate, however, that pregnant sows cannot obtain from alfalfa hay alone sufficient nourishment for maintenance, to say nothing of providing a reserve in flesh to help support the later demands of milk production. When it is remembered that the sow will lose from 30 to 50 pounds in farrowing, and that full rations are usually insufficient to prevent a further loss during the nursing period, it would appear that such restricted feeding during gestation is strongly to be advised against, except in situations of dire necessity. Such sows cannot be expected to continue to function as breeders without allowing them considerable time out for recuperation.

Replacing tankage with alfalfa meal. Freeman of the Michigan Station [13] divided the entire herd of sows and gilts into two equal groups and studied experimentally the possibility of substituting ground alfalfa hay for tankage during the winter gestation period. In these trials the grain consisted of two parts ground corn and one part ground oats. Lot I was fed in addition an allowance of tankage, which amounted to 5 percent of the ration. Lot II was fed ground second-cutting alfalfa hay in place of the tankage. The amount of hay given was such as to constitute 20 percent of the ration. The feeds of each ration were mixed and fed by hand in amounts to have the sows in both lots in the same good condition at farrowing time.

From a preliminary compilation of the results, the author concluded as follows: "The average results per litter were very close together for the first 13 litters from the tankage-fed sows and 17 litters from the alfalfa-fed sows. The percentages of strong, medium, weak, and stillborn pigs from the two groups were nearly equal. The average weight per pig from the alfalfa-fed sows was 2.90 pounds compared to 2.77 pounds for tankage and the litters from the alfalfa fed sows were slightly larger." The feed cost per sow for the 100 days of the gestation period was \$5.61 for the sows fed tankage and \$4.74 for those fed the alfalfa.

In two experiments at the Pennsylvania Station, Grimes and Havner [14] studied the possibility of replacing tankage with alfalfa hay when the latter was fed in the long condition in a rack. In all, 10 mature sows were fed during the winter gestation period a ration of shelled corn and alfalfa hay in a rack. One pound of corn in this

[13] V. A. Freeman, *Exp. Sta. Rpt.*, June, 1934, and Letter, Feb., 1935.
[14] M. F. Grimes and H. H. Havner, Bul. 168, 1921.

ration was fed daily to each hundredweight of sow. A second comparable group of sows was hand-fed a combination of 10 parts shelled corn and one part tankage. The sows getting alfalfa were fed 2.08 pounds of hay and 4.08 pounds of corn daily. Those receiving the tankage ration were fed daily 5.91 pounds of corn and 0.58 pound of tankage. The authors concluded that these rations were about equally satisfactory, although the maintenance cost was less with the alfalfa ration.

In the same experiment another comparable group of sows was fed a grain mixture of equal parts corn meal, ground oats, and wheat middlings. This ration did not prove superior to either of those just studied, and was more costly.

Protein concentrates not so necessary with alfalfa hay. The question whether bred gilts require a protein concentrate when alfalfa hay is fed was studied experimentally by Morrison and associates of the Wisconsin Station [15] and Carroll of the Illinois Station.[16] At both stations the alfalfa was of fine quality and fed in the long condition in open racks. The amount fed, some of which was wasted, averaged 0.86 pound daily in the Illinois trials, and 0.48 pound daily in the Wisconsin trials. In each experiment one of the two comparable groups of gilts was given a small feed of tankage, amounting on the average from 0.25 to 0.30 pound daily for each gilt. Ear corn was the grain fed in the Wisconsin trials and equal parts of ground corn and ground oats in the Illinois trials. The amount of grain fed during the winter was regulated by the weight and condition of the gilts. Approximately two pounds of concentrates were fed daily for each hundredweight. The gilts weighed between two and three hundred pounds when the experiments began. A good mineral mixture was self-fed to both groups in the Illinois trials. At both stations all groups had the free range of open lots for exercise.

The Wisconsin results, which are based on four years' work, were favorable to the use of the tankage supplement, although they were fairly satisfactory on the corn-alfalfa ration without the tankage. The gilts which received the tankage, however, produced slightly heavier and stronger pigs. In the Illinois trials 15 gilts in all were fed tankage and 15 the corn, oats, and alfalfa-hay ration with minerals alone. The latter consumed slightly more alfalfa than did those getting tankage

[15] F. B. Morrison, Bul. 400, 1928.
[16] W. E. Carroll, A. H. Mimeo. No. 314, 1935.

in addition. In these trials the results, so far as the weight and strength of the pigs produced are concerned, were practically identical.

It would appear from these experiments that the safety of a ration of grain and alfalfa hay without a protein supplement for bred gilts during the winter would depend principally on the quality of the hay offered, the supply of minerals, and the care which is exercised in limiting the amount of grain fed. When as much as three-quarters to one pound of hay is consumed daily by each gilt, and a mineral mixture is provided, it is a question whether a protein concentrate would be necessary. Usually, however, the hay is not of a quality to ensure as large a consumption as this. Although alfalfa is fairly rich in calcium and the other mineral elements, gilts not receiving an animal supplement like tankage, fish meal, buttermilk, or skim milk should be provided with a mineral mixture in the self-feeder, even when the hay is of the best quality. With plenty of range and an open winter, however, they seem to be able to obtain sufficient of these elements from the soil to escape any serious deficiency.

Five per cent of alfalfa meal insufficient during gestation. Early studies by Hogan of the Missouri Station [17] showed that confined sows fed a ration containing 5 percent of alfalfa meal raised only 51 percent of their pigs, while those sows which received the same basal ration, but with 15 percent alfalfa meal, raised 81 percent.

Experiments at the Wisconsin Station [18] demonstrated that confined sows failed to reproduce normally when fed during the gestation period a ration of 82 percent yellow corn, 11.5 percent soybean oil meal, 5 percent ground alfalfa hay, 1 percent limestone, and 0.5 percent salt. When the alfalfa was increased to 15 percent, replacing the corn, the sows weaned twice as many pigs and the litters were 25 percent heavier at weaning time than those from the sows which received only 5 percent alfalfa. When gilts from these sows fed the 5 percent alfalfa ration were continued on this diet, the effects were even more pronounced than in the first generation. These results were confirmed by later studies at the same Station.

Workers at the Illinois Station [19] also report that a so-called balanced ration of ground yellow corn, expeller soybean oil meal, 5 percent alfalfa meal, minerals, and vitamins A and D was found to be

[17] A. G. Hogan, Res. Bul. 167, 1932.
[18] O. Burr Ross, Paul H. Phillips, and G. Bohstedt, *Jr. An. Sci. Abs.*, Vol. 1, No. 4, 1942.
[19] J. L. Krider, L. V. Curtin, H. D. Wallace, S. W. Terrill, Mimeo. A.S.1b, 1948.

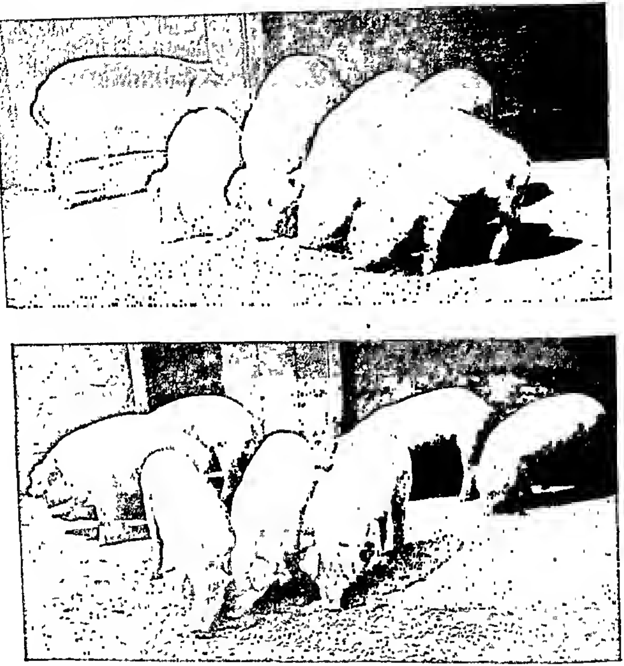

Fig. 8. Showing contrast in the results at weaning time of feeding the mothers during the gestation period 5 percent of alfalfa meal (upper) as against 15 percent (lower) *(courtesy, Dr. G. Bohstedt, Wis. Agr. Exp. Sta.).*

nutritionally inadequate for gestation and lactation under dry-lot conditions. Gilts fed this ration weaned only 26 percent of their pigs, which averaged only 17 pounds at eight weeks. When 10 percent of dehydrated alfalfa meal was added to the above ration, making 15 percent, comparable sows weaned 9.8 pigs per litter, or 91 percent of those farrowed.

Pregestation rations affect farrowing results. Vestal and associates of the Indiana Station [20] planned an experiment in which the pregesta-

[20] C. M. Vestal, W. M. Beeson, F. N. Andrews, L. M. Hutchings, and L. P. Doyle, Mimeos. 27 and 34, 1947 and 1948.

tion as well as the gestation period was considered in the feeding program. Spring-farrowed gilts were divided into three equal lots soon after weaning and fed the test rations shown below.

Lot I, in dry dirt lot, received the basal ration only.

Lot II, in dry dirt lot, received the basal ration only in the first experiment, and 5 percent of alfalfa meal in the second.

Lot III received the basal ration only on alfalfa pasture.

The basal ration was composed of ground yellow corn, soybean oil meal, steamed bone meal, pulverized limestone, iodized salt, and concentrated cod liver oil, the proportions of corn and soybean oil meal being varied so that each group received approximately the same amount of protein. After breeding, in November and December, the gilts remained in the same lots and were continued during gestation on the same basal rations with the following additions: Lot I, basal ration only; Lot II, basal ration plus 15 percent alfalfa meal; Lot III, basal ration with winter alfalfa pasture. These gestation rations were continued in the respective lots until one week after farrowing when they were fed a milk-producing ration composed of corn, oats, protein, and mineral supplements on rye pasture. The results in breeding failures, and number and weight of the pigs farrowed and weaned per litter are averaged for the two years and shown in Table 10.

Table 10. Alfalfa versus No Alfalfa during Pregestation and Gestation Periods of Gilts

(Average 2 Experiments)

	Lot I	*Lot II*	*Lot III*
Pregestation Rations	*Basal Dry Lot*	*Basal + 0 and 5% Alfalfa m. Dry Lot*	*Basal + Alfalfa Pasture*
Gestation Rations	*Basal Dry Lot*	*Basal + 15% Alfalfa m. Dry Lot*	*Basal + Alfalfa Pasture*
Number gilts bred	26	26	26
Number gilts farrowed	23	23	22
Number pigs farrowed per litter	7.8	9.4	8.3
Birth weight of pigs, lb.	2.36	2.40	2.59
Percentage stillborn and died first 3 days	30	15	10
Number pigs weaned per surviving litter	5.4	7.1	6.6
Weight at weaning, lb.	23.1	24.5	25.2
Number pigs weaned per gilt farrowed	3.57	6.83	6.6

The number of gilts which failed to settle during the breeding season was about the same, namely, three, three, and four in the respective lots. Those getting alfalfa meal or alfalfa forage farrowed larger litters of pigs, which were slightly heavier in weight at birth. Fifty-four percent of the pigs farrowed by the gilts which received the basal ration only were dead at birth or died before weaning; those which got alfalfa meal or alfalfa pasture in addition to the basal ration lost 31 and 21 percent, respectively. Eight of the 23 gilts on the basal ration only lost all their pigs; those which received alfalfa meal lost one complete litter, and those on alfalfa pasture lost none. The cumulative effect of all these losses is shown by the number of pigs weaned per litter farrowed. The gilts which received either alfalfa meal or had alfalfa pasture raised nearly double the number of pigs per litter than those that had been fed the basal ration only.

In the first of these two experiments the gilts in Lot II received during the growth or pregestation period the basal ration only; in the second, Lot II received in addition to the basal ration 5 percent of alfalfa meal during this period. Although the results for the two years are not exactly comparable, it is permissible to note that when limited to the basal ration only during the pregestation period the gilts of Lot II lost 46 percent of their pigs, raising only 5.8 per litter farrowed, while when 5 percent of alfalfa meal was fed during this time the gilts of Lot II lost only 16 percent of their pigs, raising 7.5 per litter farrowed. Gilts that have been properly fed during the growth or pregestation period are much less likely to suffer from defective rations fed during gestation; and the best of conditions and feeding during gestation cannot overcome completely the carry-over effects of defective rations fed during the previous growth period.

Other legumes valuable for winter feeding. Although alfalfa is somewhat more palatable, greener, and more richly endowed with protein, minerals, and vitamins, other legumes, such as the clovers, soybean, and cowpea hay, when of good quality, may be fed to pregnant sows and gilts during the winter with the expectation of nearly the same benefits. Ten pounds of alfalfa leaf meal, because of its lower fiber content and richer supply of proteins and vitamins, will take the place of 15 pounds of good-quality alfalfa meal.

Green forage crops are of highest value. There is no surer or more practical way of ensuring a supply of those food factors commonly missing in many so-called good gestation rations, the absence of which are responsible for a large share of baby pig losses, than that of pro-

viding green forage crops for winter grazing. Only in their absence, or partial absence, is it necessary to incorporate alfalfa or other legume hay in the ration. One of the most important advances in better feeding practice that has been made in recent years has resulted from the effort to provide as nearly as possible summer grazing conditions during the winter months.

Winter grazing can be provided by the southern pork producer with little difficulty. He has available a variety of legumes and grasses from which to choose, such as, alfalfa, clovers, soybeans, cowpeas, vetch, rye, sudan, barley, oats, bermuda grass, rape. Because of the large proportion of white to yellow corn in the South, the need for vitamin A, abundantly supplied by green forage, is more critical than in the North. Probably the best late-fall, winter, and early-spring forage in the North is Balbo rye. It stays green, is unusually palatable, and is a heavy yielder when grown on good soil. Krider and associates at the Illinois Station demonstrated experimentally that bred gilts on rye pasture during the winter produced a high percentage of strong pigs, and that the residual or carry-over effect was such that these gilts when confined to the dry lot and fed only the vitamin-deficient basal ration during lactation, weaned 90 percent of their pigs, whereas those gilts that had received only the basal ration during gestation and lactation weaned only 26 percent. The gilts would root in the snow to obtain the green feed.

The value of an alfalfa pasture for winter grazing of bred sows was shown in the experiments of Vestal and associates of the Indiana Station (see page 47). Like rye, it supplies considerable amounts of those critical food factors so needed to produce strong pigs. Winter wheat also will often supply valuable grazing during the winter and early spring without damage to the subsequent crop.

In addition to the important function of supplying certain needed food factors during gestation, these green crops encourage exercise in the open, reduce the cost of maintenance, and ensure the maintenance of that laxative condition of the bowels so essential to a high state of health or thrift.

Wheat-germ meal as a supplement. During a four-year period Aubel and associates of the Kansas Station [21] ran tests, three with gilts and one with yearling sows, to determine the effect on farrowing and weaning results of adding fresh wheat-germ meal to a basal gestation and lactation ration of ground yellow corn 75 percent, tankage 10 percent,

[21] C. E. Aubel, J. S. Hughes, and H. F. Lienhardt, Tech. Bul. 31, 1932.

alfalfa leaf meal 10 percent, bone meal 5 percent, salt and cod liver oil. Wheat germ is known to be a rich source of several nutritionally important factors, such as vitamin E and several of the fractions of the B-complex vitamins. In the test ration 10 percent of wheat-germ meal replaced an equal amount of corn. The authors reported that the results were not strikingly different in the two lots, although the sows which received the wheat-germ meal farrowed slightly more live pigs, raised a higher percentage, and were somewhat better milkers.

Calcium important during pregnancy. The failure of sows to raise their pigs is often the result of an insufficient supply of minerals in the ration fed during the period of pregnancy. This is especially true in the case of the element calcium, which is found in very meager amounts in the cereal grains and which, with phosphorus, is the chief element employed in the growth of bone and the manufacture of the casein of milk.

Evans of Cambridge University [22] maintained mature sows through several successive gestation and lactation periods on a ration which was adequate in all respects except in its supply of calcium. During this time the sows were kept in concrete-paved pens under strictly controlled conditions. On this ration, which contained but 0.034 percent of calcium, 7 litters of 76 pigs were farrowed. Of these, 52 were alive at birth, and 34 dead; only 10 of them lived to weaning time. One sow raised 4 pigs which averaged 18.78 pounds at weaning time, and another raised 6 which averaged 9.62 pounds when weaned.

The typical manifestations from the calcium-deficient rations were described by the author as follows:

> (1) Rough, scaly skins, dirty in appearance. (2) The pigs were periodically 'off their feet' with their legs bending inwards, and developed what appeared to be characteristic signs of rickets. (3) The sows often refused their food towards parturition, this indicating nutritive disturbances. (4) They had great difficulty in farrowing and could not stand on their feet for two or three days afterwards. (5) No signs of milk could be seen before or after farrowing, and their udders were very flabby especially in comparison with the normal sows. (6) Very few pigs survived at weaning time and even the few left made very poor live weight gains. It should be observed, however, that the sows themselves when they farrowed appeared to be in good condition.

From a comparable group of sows similarly treated and fed the same ration supplemented by the addition of 1½ percent of ground limestone (85 percent $CaCO_3$), normal results were secured. The

[22] R. E. Evans, *Jour. Agr. Sci.*, Vol. 19, 1929.

amount of calcium contained in this ration amounted to 0.59 percent.

Similar disastrous results are reported by Hogan of the Missouri Station,[23] who fed a ration about equally deficient in calcium to gilts throughout the gestation and lactation periods. From experiments covering several years he concluded that rations for brood sows should contain not less than 0.40 percent of calcium.

Feeding experiments supplemented with chemical studies of the products of pregnancy by Hart and associates of Wisconsin,[24] Mitchell and associates of Illinois,[25] and Evans of Cambridge University[26] indicate that for good nutrition during the gestation period the ration for the pregnant sow or gilt should contain from 0.40 to 0.56 percent of calcium. This is approximately the same as the amount recommended for the growing pig (see page 170). This supply would appear to be sufficient not only to provide for the demands of the foetal litter, but sufficient also to ensure a large body reserve to serve the later demands of milk production. That well-fed sows do store large reserves of calcium during pregnancy was shown by the studies both of Mitchell and Evans.

The latter calculated that the mature sows fed the calcium-rich ration in his experiments stored in their own bodies during gestation four times the amount which was deposited in the foetuses. Mitchell[27] estimated that the dry ration of pregnant gilts weighing 250 pounds should contain 0.22 percent calcium during the eighth week of gestation and 0.43 percent during the sixteenth week, assuming an adequate supply of vitamin D. As gestation advances, the need for calcium increases relative to the demand for phosphorus. During the sixteenth week the most ideal calcium-phosphorus ratio was estimated to be 1.5 to 1, while during the eighth week it was 1.1 to 1.

Although the sow requires about the same amount of phosphorus as calcium to meet her needs, the relative abundance of this element in the cereal grains and protein supplements, although of low availability, especially in the presence of an excess supply of calcium, makes it unnecessary as a rule to incorporate special phosphorus-carrying ingredients in the mineral mixture.

Common salt is essential. Next to calcium, common salt is the mineral most likely to be supplied in insufficient amounts. That its

[23] A. G. Hogan, Res. Bul. 167, 1932.
[24] Res. Bul. 30, 1914.
[25] Bul. 375, 1931.
[26] R. E. Evans, *Jour. Agr. Sci.*, Vol. 19, 1929.
[27] H. H. Mitchell, and F. J. McClure, Bul. 99, National Res. Council, 1937.

use in regular and moderate amounts is essential to health and good breeding performance is assumed by all breeders and students of nutrition.

In experiments by Evvard and associates of the Iowa Station [28] with yearling-bred sows it was estimated that they consumed during the winter an amount of salt equivalent to 0.25 percent of the dry ration. Evans [29] found that normally fed sows in his experiments retained in their bodies approximately 1¾ times as much calcium as of common salt. From what is known concerning the requirements of the growing pig, also, it may be concluded that salt should make up *one-fourth to one-third* of the usual calcium-rich simple mineral mixture.

The most practical method of feeding salt is either in a simple mineral mixture, such as one part of limestone dust, one part of steam bone meal, and one-half to one part of salt; or by itself, in a second compartment of the mineral feeder. Pressed block salt is not suitable because of the difficulty which hogs have in eating it.

Iodine prevents hairless pigs. Another mineral element of economic importance is iodine, because of its relation to "hairlessness" in young pigs. In the so-called goiterous or semigoiterous areas of the North and Northwest, in the region of the Great Lakes, because of a natural deficiency in the iodine content of the soil, the young are frequently born with "big-neck" or goiter, the result of, or an accompaniment of, an enlarged thyroid gland. In the case of pigs, they are born practically bald and without hair; the skin of the neck and face is thick and puffy, and the thyroid gland is enlarged from the normal size of a pea to that of a hickory nut. The mothers of such pigs also have an enlargement of the gland, to the size of a man's fist, but the general health of the sow apparently is not affected. Pigs so born are dead at birth or die soon after. Sometimes only part of the litter is afflicted. The malady is more common in spring- than in fall-farrowed litters, and more likely to occur following a long severe winter than an open one. The pigs are of normal size and weight and are always carried full time or over.

Hairlessness can be prevented by supplying the pregnant mother minute quantities of potassium or sodium iodide. Welch of the Montana Station [30] successfully prevented the trouble in 23 herds, in most

[28] John M. Evvard, I. W. Wallace, and C. C. Culbertson, Bul. 245, 1927.
[29] R. E. Evans, *Jr. of Agr. Sci.*, Vol. 19, 1929.
[30] H. Welch, Bul. 119, 1917.

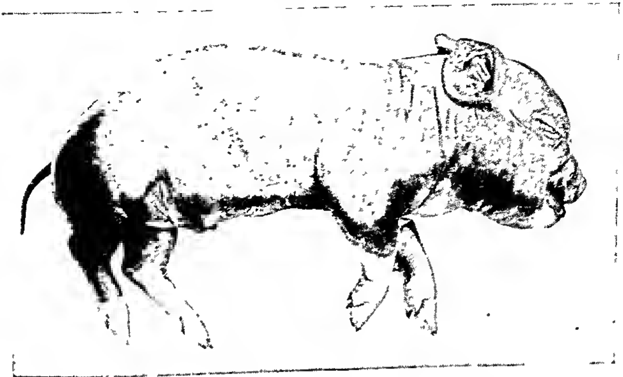

Fig. 9. This pig was born hairless and dead due to iodine deficiency in the diet of the mother during pregnancy *(courtesy, Dr. H. Welch, Mont. Agr. Exp. Sta.)*.

of which the malady was common the previous year, by feeding 2 to 3 grains of potassium iodide daily to each sow during 100 days of the gestation period. A tablespoonful of a solution made by dissolving 1 ounce of the salt in 1 gallon of water contains about 2 grains and is equivalent to a daily dose. Kalkus of the Washington Station [31] reported that enough iodine would be absorbed through the skin to prevent its occurrence when 1 cubic centimeter of tincture of iodine was poured on the back of the sow once a week during pregnancy. Later studies indicate that as little as 1 to 2 grains of potassium weekly during the last three-quarters of the gestation period are adequate to prevent the trouble. The practical solution of the problem of prevention is simple: feed stabilized iodized flake salt instead of straight salt in all goiterous and semigoiterous areas. Welch of the Montana Station [32] says: "The repeated occurrence of goiter on farms where the pressed blocks of iodized salt are used indicates that this type of salt is not satisfactory for goiter prevention."

There are a dozen and more mineral elements known to be necessary in the nutrition of swine, but, with the exception of those just discussed, there is no convincing evidence that the usual well-balanced

[31] J. W. Kalkus, Bul. 153, 1919.
[32] Howard Welch, Cir. 160, 1940.

ration made up mainly of farm feeds grown on soil that is not markedly deficient in any one element will not provide them in adequate amounts.

Concerning the inclusion of iron in the mineral mixture during pregnancy with the idea of minimizing the danger of anemia in the young pigs after birth, Mitchell and McClure of Illinois University[33] have this to say: "The nutrition of the sow prior to or during lactation is entirely unrelated to the occurrence of nutritional anemia in her pigs except as the pigs may have access to and consume the sow's feces, because neither the iron content of the ration nor the copper content appears to affect the concentration of these metals in the milk produced by lactating animals."

Vitamins necessary for reproduction. Vitamins represent a class of little-known chemical food factors, separate from the carbohydrate, fat, protein, and mineral classes of nutrients, which are required in minute amounts for the support of some phase of animal life. They do not constitute a direct source of energy nor do they supply materials for tissue growth but exercise their influence apparently through catalytic and other effects on certain of the chemical processes of metabolism. Fifteen or more of these factors have been identified and their nutritional importance investigated. Most of them are contained in natural feedstuffs in amounts sufficient for growth and reproduction. Many of the manufactured by-product feeds, as well as the cereal grains, however, are notably deficient in some of them. One of these is vitamin A.

White corn is deficient in vitamin A. At the Illinois Station Rice and associates[34] compared white with yellow corn for yearling and two-year-old sows. Starting at breeding time, early in December, one group of four sows was fed yellow corn and a comparable group white corn. In addition, each lot received tankage and either yellow or white corn bran. The sows were confined to open dry lots and were rebred as soon as possible after weaning their pigs. The experiment, beginning with four sows to each lot, was continued through several successive gestation and lactation periods with a diminishing number of sows. The purpose was to determine how soon and to what degree the vitamin A deficiency in the white-corn ration would affect the ability of the sows to reproduce and nourish their pigs.

From this study the authors concluded as follows: "Brood sows

[33] H. H. Mitchell and F. J. McClure, Bul. 99, Nat. Res. Council, 1937.
[34] John Rice, H. H. Mitchell, and R. J. Laible, Bul. 281, 1926.

raised upon well-balanced rations may withstand the ill effects resulting from the deficiency of vitamin A in white corn rations for two gestation and lactation periods, though eventually their fertility is impaired. Furthermore, pigs farrowed in the first two litters on white corn feeding may grow as rapidly during the suckling period as other pigs farrowed from sows subsisting upon yellow corn rations. Evidently enough vitamin A is stored in the sow during a protracted period of adequate feeding to supply the requirements of two litters of pigs up to weaning time."

Martin of the Arkansas Station [35] found that well-grown gilts were unable to raise their pigs when fed a ration of white corn and tankage during the gestation period. During two years, six gilts which had been on this ration from breeding to farrowing time gave birth to 52 apparently normal pigs, but only four of these lived to weaning age. Most of the pigs were dead by the end of the first week after birth. On the other hand, when chopped or ground alfalfa hay was added to the white-corn–tankage ration in an amount to constitute from 10 to 15 percent of the ration by weight, normal results were secured. Tomhave of the Delaware Station [36] concluded from experiments with bred sows that alfalfa leaves supply some food essential that is lacking in a ration of white corn, tankage, and minerals.

Studies by Hughes and associates of the Kansas Station [37] showed that when the feeding of a vitamin-A–deficient ration is begun soon after weaning, the ability of gilts to reproduce is seriously impaired. In this test there were eight gilts in the experimental group. The vitamin-A–deficient ration was composed of 87 percent white corn or kafir, 10 percent tankage, and 3 percent bone ash. The gilts were confined to open cement-paved lots connected with a barn for shelter.

Significant points in the results observed may be enumerated as follows: In due time five of the eight gilts were bred, the other three, though apparently in heat, would not take the boar. Of the five which were bred, one sow aborted six dead pigs 86 days after breeding, another sow aborted nine pigs 87 days after breeding, a third gave birth to ten dead pigs at the normal time, and another died nine days before she was due to farrow. Postmortem of this sow showed 10 apparently normal foetuses in the uterus. The fifth sow was killed 81 days after breeding for experimental examination, at which time the

[35] Edgar Martin, *Proc. Am. Soc. An. Prod.*, Jan., 1930.
[36] A. E. Tomhave, Bul. 147, 1926.
[37] J. J. Hughes, C. E. Aubel, and H. F. Lienhardt, Tech. Bul. 23, 1928

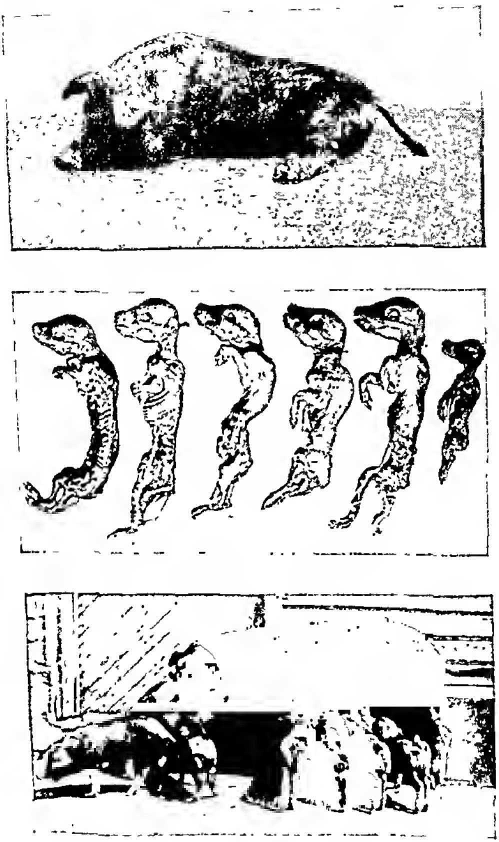

Fig. 10. Vitamin A is necessary for reproduction (*Kansas Exp. Sta., Tech. Bul.* 23).

Upper: Pregnant sow No. 13 in the Kansas experiment, showing pronounced muscular incoordination after 356 days on a vitamin-A–deficient ration.

Middle: Partially resorbed foetuses taken from above sow on post-mortem examination 81 days after she was due to farrow.

Lower: This sow had been fed the same vitamin-A–deficient ration as No. 13 above, but with the addition of 10 percent prime alfalfa meal.

uterus contained six partially resorbed foetuses. The authors concluded, in view of the negative character of the tests for contagious abortion, that the lack of vitamin A in the diet was responsible for the disastrous results noted.

Hale of the Texas Station[38] demonstrated the relation between a vitamin-A–deficient diet and blindness in pigs. He found that when gilts were fed a vitamin-A–deficient ration for a period long enough to deplete their vitamin A body reserves by the time they were bred, and for 30 days after breeding, the pigs were born blind or were without eyeballs. The pigs appeared normal in other respects, but most of them died within a few minutes after birth. Subsequent breeding tests showed that the eye condition was not the result of a hereditary defect in the experimental animals.

Barley is deficient in vitamin A. Two experiments covering three years by Hughes and Hart of the California Station[39] showed that the carotene or vitamin A content of a ration made up of 96½ percent rolled barley, 1½ percent casein, 1 percent common salt and 1 percent calcium carbonate was insufficient for growth and reproduction. Five spring gilts were placed on this diet under controlled conditions soon after they were weaned. The following autumn every effort was made to breed them. One gilt only became pregnant, but all the foetuses were resorbed during gestation. There was therefore 100 percent failure to secure reproduction. This same ration, with 5 cubic centimeters of cod liver oil daily, was fed to a comparable group of six gilts at the same time. In two years this group of gilts, restricted to this ration during the entire time, produced 10 litters, 7 of which were classified as strong and 3 as weak. Results from another group of gilts showed normal reproduction also when 10 percent of chopped alfalfa hay was included in the ration.

In the Illinois trials yearling and two-year-old sows that had been well grown on complete rations were used. Furthermore, experimental feeding did not commence until the sows were bred, at which time their bodies presumably were well fortified with vitamin A reserves. In the Kansas and California trials, on the other hand, the gilts were started on the experimental ration soon after they were weaned, with the result that their reserves of this vitamin were probably exhausted by the time they were bred. These facts explain the more prompt and striking manifestations of vitamin A starvation which were observed in the latter studies.

[38] Fred Hale, 47th An. Rpt., 1932–35.
[39] E. H. Hughes and G. H. Hart, *Jr. Agr. Res.*, Vol. 49, No. 10, Nov., 1934.

were fed during the gestation period a ration composed of yellow corn, tankage, linseed oil meal, fine alfalfa meal (5 percent), cod-liver oil, and a suitable mineral mixture. The sows were on concrete and green forage was excluded. On this ration the pig losses were heavy and the surviving pigs small and unthrifty. When this ration was supplemented during the last two months of the gestation period by adding sources of several of the B-complex vitamins, there was an improvement in the results.

Similar studies of gestation rations at the Wisconsin, Illinois, and Indiana Stations, which have been reviewed in this chapter in relation to alfalfa feeding, showed that a marked reduction in baby pig losses was effected by increasing the amount of alfalfa meal from 5 to 15 percent, or by providing green forage. Since the supply of vitamins A and D, as well as of the proteins and minerals, in the basal rations was adequate, a large part of the improved farrowing and weaning results must be attributed to some or all of the vitamins of the B-complex group contained in these two natural feeds.

Rich sources of the more common B-complex vitamins, extensively employed in the manufacture of commercial vitamin supplements, are the dried fermentation solubles, such as dried distillers' solubles, dried brewers' yeast, and condensed fish solubles.

Vitamin B_{12} related to pig survival. There now is evidence, however, that feeding as much as 15 percent of good alfalfa meal in a first-class ration during the gestation period, particularly when the protein contained is chiefly of plant origin, does not provide all the dietary factors needed to produce strong pigs. This is illustrated by the results of an experiment reported from the Indiana Station,[41] the main purpose of which was to test the value in a gestation ration of vitamin B_{12}, as contained in Merck's "animal protein factor" (APF).

Four lots, each of 12 spring pigs, were fed during the summer a corn-soybean meal-alfalfa (5 percent) ration with minerals and cod-liver oil, in paved lots. On September 14 they were changed to the following gestation rations, respectively:

Lot I—Basal ration, corn, soybean oil meal, alfalfa meal (15%), simple mineral mixture, and cod-liver oil.

Lot II—Basal ration + vitamin B_{12} supplement, fed at the rate of 2 milligrams of B_{12} per 100 pounds of feed.

Lot III—Basal ration + vitamin B_{12} supplement + vitamin E, 1 gram (mixed tocopherols) per gilt daily.

[41] C. M. Vestal, W. M. Beeson, F. N. Andrews, L. M. Hutchings, and L. P. Doyle. Mimeo. No. 50, Sept., 1950.

Cereal grains and most by-products deficient in vitamin A. None of the cereal grains, except yellow corn, contain appreciable amounts of carotene, which after assimilation in the body produces vitamin A; neither do the cereal or animal by-products, including skim milk and buttermilk. Feeds that are especially rich in vitamin A potency are lush green forage and fine-quality green hay. Hay that has lost its color, as a result of weathering or long storage, however, is of little value. For winter feeding, an amount of quality alfalfa or other legume hay sufficient to represent about 15 percent of the dry ration by weight, or access to succulent forage during the summer, provides practical and effective means of ensuring an adequate supply of this vitamin for pregnant sows and gilts.

Vitamin D important in winter feeding. All classes of animals require vitamin D, known as the antirachitic vitamin. It is also frequently referred to as the "sunshine vitamin," since the action of sunlight on the body surface results in the formation of the vitamin D substance. It is a factor of practical importance in feeding pregnant sows and gilts during the winter, since the amount and potency of sunlight available during this season is often so limited that the supply of vitamin D in the ration requires attention.

Grains and the other usual feed concentrates contain little if any vitamin D. Green forage has none, but after cutting and exposure to the sun its content is considerable. Alfalfa cured under caps, although high in vitamin A, will have much less vitamin D than that which has been cured in the usual manner. During the summer, the amount of available sunshine makes unnecessary a special supply of vitamin D in the ration for hogs in the open. Sunshine and sun-cured quality hay normally ensure a farm supply of this vitamin sufficient to meet the needs during the winter without resort to irradiated yeast, cod-liver oil, or special commercial sources containing these vitamin-rich ingredients. When the amount of quality alfalfa or other sun-cured legume hay is fed in the amount sufficient to take care of the vitamin A and other vitamin demands, namely, 15 percent of the dry ration, the vitamin D requirements will be amply provided.

Vitamins of B-complex group important. That several vitamins of the B-complex group are also necessary for good brood-sow performance, and pig survival has been demonstrated recently in a number of carefully controlled experiments. Hogan and McRoberts of the Missouri Station [40] in feeding trials covering several years were unable to secure normal farrowing and weaning results when the sows

[40] A. G. Hogan and V. F. McRoberts, *Proc. Am. Soc. An. Prod.*, Dec., 1940.

were fed during the gestation period a ration composed of yellow corn, tankage, linseed oil meal, fine alfalfa meal (5 percent), cod-liver oil, and a suitable mineral mixture. The sows were on concrete and green forage was excluded. On this ration the pig losses were heavy and the surviving pigs small and unthrifty. When this ration was supplemented during the last two months of the gestation period by adding sources of several of the B-complex vitamins, there was an improvement in the results.

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Four lots, each of 12 spring pigs, were fed during the summer a corn-soybean meal-alfalfa (5 percent) ration with minerals and cod-liver oil, in paved lots. On September 14 they were changed to the following gestation rations, respectively:

Lot I—Basal ration, corn, soybean oil meal, alfalfa meal (15%), simple mineral mixture, and cod-liver oil.

Lot II—Basal ration + vitamin B_{12} supplement, fed at the rate of 2 milligrams of B_{12} per 100 pounds of feed.

Lot III—Basal ration + vitamin B_{12} supplement + vitamin E, 1 gram (mixed tocopherols) per gilt daily.

[41] C. M. Vestal, W. M. Beeson, F. N. Andrews, L. M. Hutchings, and L. P. Doyle. Mimeo. No. 50, Sept., 1950.

Lot IV—Basal ration + vitamin B_{12} supplement + condensed fish solubles, fed as 2 per cent of the ration.

During the nursing period all gilts with their litters were on Balbo rye pasture, and received a ration of ground corn and oats with protein and mineral supplements.

Table 11. Vitamin B_{12} (Merck's APF) in the Gestation Ration of Gilts

	Number Gilts Farrowed	*Average No. Pigs Farrowed per Litter*	*Average Birth Weight per Pig*	*Pigs Weaned per Litter Farrowed*	*Percentage Farrowed Pigs Weaned*	*Average Litter Weight at Weaning*
			lb.			lb.
Basal	9	8.6	2.20	4.8	55.8	153.3
Basal + vitamin B_{12}	10	9.7	2.36	7.5	77.3	170.8
Basal + vitamin B_{12} + vitamin E	10	9.4	2.49	6.9	73.4	177.2
Basal + condensed fish solubles	10	10.0	2.22	7.1	71.0	161.0

Compared with the gilts fed the basal ration containing 15 percent of alfalfa meal, those that received the vitamin B_{12} supplement in addition farrowed larger and stronger pigs; the death losses were much lighter despite a larger number farrowed, and the weaning weights per litter were considerably heavier. Death losses the first three days after farrowing for the different lots were as follows: Lot I, 24.7 percent; Lot II, 10.3 percent; Lot III, 8.5 percent; Lot IV, 10.0 percent.

The addition of vitamin E to the test ration produced pigs with the heaviest birth weight, the lowest death losses after birth, and the heaviest final litter weight. Feeding condensed fish solubles, a semisolid by-product from the fish packing industry, as an addition to the test ration did not appear to be of any benefit.

Similar results were secured by Anderson and Hogan of the Missouri Station.[42] They showed that by feeding Merck's APF No. 3 to pregnant gilts in an amount to represent 1 milligram of vitamin B_{12} per 100 pounds of feed as an addition to the basal ration composed of corn, tankage, soybean oil meal, alfalfa meal (2½ percent), cod-liver oil, and a complex mineral mixture, the number of pigs born alive was increa[illegible] 96.7 percent to 100 percent, and the weaning weight per pig [illegible]

[42] G. C. Anderso[illegible] 'ol. 9, No. 4, 1950.

Carpenter of the Hormel Institute,[43] however, found that the feeding of an APF supplement containing aureomycin (B12 + aureomycin) to two groups of sows for 49 and 90 days, respectively, just prior to parturition, as an addition to a basal ration containing 4 to 6 percent of tankage, with linseed and soybean oil meal, and 10 percent of alfalfa meal, did not affect the livability of the pigs.

FORMULATING SUITABLE RATIONS

As we have seen, the successful nourishment of pregnant sows and gilts requires that special attention be given to the supply of proteins, minerals, and vitamins. Resulting from the abundance of corn or other cereals in the pork-producing areas, the carbohydrate and fat supply is not a matter of practical concern, except if the feeder places too great a reliance on them.

Recommended allowances of critical nutrients. The allowances of these nutrients which are recommended for rations during the gestation period are shown in Table 12. The figures given are higher than those representing the minimum requirements, so far as these are known, in order to allow for variations in composition which occur in the same feed, and for differences in the availability of the same nutrient from different sources. The smaller of the two figures is the amount recommended during the early part of the gestation period, and the larger, the amount during the later stages. Although rations that are balanced with respect to their organic nutrients will usually supply sufficient phosphorus, this element is included in the table because of the desirability of maintaining a calcium-phosphorus ratio close to 1¼ to 1½ : 1. The salt to be fed should be iodized in the goiterous or semigoiterous areas.

Table 12. Recommended Allowances of Critical Nutrients, during the Gestation Period, Expressed as Percentages of the Air-Dry Ration

	Crude Protein	*Calcium*	*Phosphorus*	*Common Salt*	*Vitamins A, D, and B-Complex*
	%	%	%	%	
Gilts	13–15	0.40–0.50	0.30–0.40	0.45–0.50	Amply supplied when the ration includes 10% alfalfa leaf m., or 15% good alfalfa or other legume hay, by weight, or green forage
Mature Sows	12–14	0.30–0.40	0.25–0.35	0.35–0.50	

[43] Lawrence E. Carpenter. Pub. No. 61. 1951.

Some good gestation rations. In Table 13 are a few suggested type rations which combine in fairly balanced proportions the food nutrients known to be essential for good reproduction. In some, the grains are supplemented with animal proteins; in others, with protein feeds from plant sources, and in some with a combination of both. The attempt has been made to formulate rations suited, according to the feed supplies, to the different areas of the country. The simple mineral mixture is made up of 2 parts pulverized limestone, 2 parts special steamed bone meal, and 1 part common salt. The latter should be stabilized iodized salt in the goiterous and semigoiterous areas.

Table 13. Rations for Winter Feeding Bred Sows and Gilts

Feeds	*Ration 1*	*Ration 2*	*Ration 3*	*Ration 4*
	%	%	%	%
Ground corn or grain sorghum	40	70	42	60
Ground oats	38		35	18
Tankage or meat scraps	3		4	7
Soybean oil meal	4	10	2	
Cottonseed meal			2	
Wheat shorts or middlings		8		5
Alfalfa meal	15	12	15	15
Skim milk or buttermilk		4 qts. daily		
Minerals	Simple min.mix., self-fed	Simple min.mix., self-fed		
Percentage crude protein	13.7	14.0	15.0	14.4

Feeds	*Ration 5*	*Ration 6*	*Ration 7*	*Ration 8*
	%	%	%	%
Ground oats	40	45	20	
Ground barley	35		43	79
Ground wheat		30		
Fish meal	5	2		4
Soybean oil meal			4	2
Cottonseed meal		4		
Peanut oil meal		4		
Linseed meal	5		3	
Wheat shorts or middlings			15	
Alfalfa meal	15	15	15	15
Minerals		Simple min.mix., self-fed	Simple min.mix., self-fed	Simple min.mix., self-fed
Percentage crude protein	14.5	15.3	15.4	15.2

In those rations in which a mineral mixture was not recommended, the calcium content varied from 0.43 to 0.71 percent and the phosphorus from 0.43 to 0.57 percent. Although the assumption is that no salt is required in these three rations, in addition to that contained in the feed, it will be advisable, in order to be on the safe side, to give the sows access to a supply in a self-feeder. For summer and fall feeding, green forage should be available in amount and quality sufficient to replace, in whole or large part, the alfalfa meal in these rations.

Regulating the amount fed. Good results at farrowing time are possible only when good judgment is used in regulating the amount fed. Even with the best of rations, plenty of exercise, and comfortable houses, it is possible by careless feeding greatly to reduce the chances of a good pig crop. What was said concerning the food demands of the sow at the beginning of this chapter suggests the desirability of a gain of 75 to 85 pounds during the gestation period as a preparation to meet the losses which normally occur later in farrowing and lactation (see Fig. 7, p. 31). Gilts should gain from 75 to 100 pounds. Extremes in condition should be avoided. The extremely fat sow is a pig killer and, because of her usual disposition to take little exercise, her pigs are weak at birth. It also means a waste of feed and excessive cost for maintenance. Likewise, an extremely thin, half-starved condition should be avoided, for such a sow will lack the reserves of energy which are needed later to help support milk production. In the interests both of economy and good results, the sow at farrowing time should be in medium to strong condition. Most of these gains, especially for the more mature sows, should be put on during the last half of the gestation period.

The amount of concentrates which it will be necessary to feed to bring about this desirable condition will depend altogether on conditions. In practice it will be affected by the condition of the sows when bred, the amount of feed that can be picked up by rustling in the fields, the weather, and the availability and quality of the legume hay. During the early part of a mild winter little will be required in addition to what can be gleaned from the fields. In Table 14 averages are presented showing the amount of concentrates, such as grain and protein supplements, actually fed daily for each 100 pounds weight of sow, and the gains obtained. The figures are based on the data of the experimental groups which have been reviewed in this chapter. Although averages cannot be applied to individual cases, they are useful as general guides and as basis for budgeting feed supplies.

The mature sows fed a balanced ration, without hay, in the first division of the table, were liberally fed; they gained during the gestation period close to 100 pounds. It may be concluded from these figures that 1¼ pounds of concentrates daily per hundredweight for mature sows would probably be sufficient for an average gain under these conditions.

Table 14. Amount of Concentrates Fed Pregnant Sows in Winter

Age of Sows	*Average Daily Gain*	*Concentrates Fed Daily per Cwt. Sow*
	lb.	lb.
Average for 117 mature sows fed balanced rations (no hay)	0.866	1.360
Average for 77 mature sows fed corn or oats, with alfalfa hay in rack	0.648	1.184
Average for 51 gilts fed balanced rations (no hay)	0.737	1.780

For mature sows having access to a good legume hay in a rack, the amount of concentrate that it is necessary to feed to ensure sufficient gain is considerably reduced. When fed corn or oats without a protein concentrate, the sows here required but little more than 1 per cent of their weight daily. With the addition of a protein supplement during the last six weeks of pregnancy, which is to be recommended, one pound per hundredweight probably would suffice under moderate weather conditions.

Gilts carrying their first litters naturally require more feed for a given unit of weight than do mature sows. It would appear from the figures in the table that 1¾ pounds daily per hundredweight would be about right under most conditions. We would expect yearling sows fed a balanced ration to require an amount intermediate between that of the mature sow and gilt, namely, about 1½ pounds daily per hundredweight. In practice, however, the point in any of these cases is to feed more, or less, than the average as needed according to the actual condition of the sow.

Preparation of feeds and methods of feeding. It makes no difference, so far as is known, whether the sows are fed their concentrates wet in the form of a slop, or dry. When the grain is ground and the feed mixed, feeding as a thick slop generally is practiced because less of the feed is wasted. When watering is by hand, little extra work is involved. More and more, however, hog raisers are being converted to

the dry-feeding method. That it requires less labor than slop feeding and gives equally good results is the verdict of those who have used both methods.

The beneficial effects of grinding are somewhat doubtful. Although corn comes through undigested and apparently in wasteful amounts when fed whole, the experimental studies made thus far indicate that grinding is of limited benefit. Breeders generally believe that grinding corn pays when facilities for it are available on the farm. In the case of oats, barley, wheat, rye, kafir, etc., grinding is beneficial if we are to judge from the results obtained with shotes, and advisable especially when the operation can be performed at home. Oats and barley should be ground fine or rolled. Wheat, rye, and kafir should be soaked if not ground. Grinding or cutting legume hay may not be practical, as against feeding it in the long condition, although this is a nice way to feed it and facilitates the exact proportioning of the different feeds in the ration. Cooking is detrimental rather than beneficial with the usual feeds.

Self-feeding practice increasing. In recent years there has been apparent an increased interest among hogmen in the self-feeding method of handling sows and gilts during the winter. The plan is especially popular where large numbers are involved and reliable help is scarce. The trend has been stimulated, too, by the general recognition of the protective nutritive value of leafy legume hay in the gestation ration, and by the fact that farmers are becoming labor-saving conscious.

Peters and Ferrin of the Minnesota Station [44] compared the usual hand-feeding with the self-feeding method with pregnant gilts during three successive winters, 1943 to 1946. A total of 83 gilts was involved. Lot I was hand-fed a ration composed of 67 percent ground yellow corn, 26 percent ground oats, 7 percent tankage, a complex mineral mixture, self-fed, and leafy alfalfa hay in a rack. Lot II was self-fed the same feeds but in regulated proportions. The alfalfa was ground and mixed with the ground corn and oats, the proportion varying from 20 to 30 percent of the mixture, by weight.

The results were not greatly different in any of the three years. The number of pigs farrowed and raised, and the weaning weights of the pigs, were satisfactory in both lots. The feed cost was a little higher in the self-fed groups since the total feed consumption was somewhat greater. The hand-fed group gained an average of 129 pounds during the gestation period, and the self-fed group 149 pounds. Only a limited

[44] W. H. Peters and E. F. Ferrin, H-54, H-55, and H-56, 1944, 1945, 1946

number of the latter group, however, were considered too fat at farrowing time. The loss of weight during the nursing period, including that lost at farrowing time, was 51 and 58 pounds, respectively.

Success with the self-feeding method would appear to depend chiefly on the care which is exercised in regulating the proportion of the alfalfa in the mixture. To keep down the consumption of concentrates and prevent over-fatness, it would seem necessary that the bulky alfalfa constitute close to one-third of the mixture, by weight. For older sows, the self-feeding method would appear better adapted than it is for gilts since their food requirements per weight are less and their capacity to consume bulky feed is greater.

Water consumption and methods of watering. The importance of a constant and easily accessible supply of water for pregnant sows and gilts cannot be overemphasized. Especially during the winter months, when a hand supply in the trough freezes quickly, and as a result of the reluctance on the part of the sow to leave her warm bed in cold weather and to travel a considerable distance to quench her thirst, there is a chance that her water consumption may fall below her physiological needs. On the other hand, the feeding of thin slops may result in an excessive overconsumption. Perhaps the most satisfactory solution of the problem is to provide self-waterers, equipped with lamps to prevent freezing, in a protected site and close to the feed supply. During the summer, the supply should be constant, conveniently located in the shade, and as fresh and cool as possible.

The amount of water required, as indicated by their free consumption, varies considerably. Young sows drink more per weight than older sows, less is consumed on forage than in the dry lot, more is required in summer than in winter, and more is consumed on rations high in fiber than on more concentrated rations. Evvard and associates of the Iowa Station [45] found that 40 yearling sows fed well-balanced rations during the winter consumed on the average 7.82 pounds daily. The consumption varied from 6.09 to 9.20 pounds for the four experimental groups, being highest in those lots where the fiber content of the ration was largest (see Table 50). The average weight of the sows was 326 pounds.

Snyder of the Nebraska Substation [46] compared two methods of watering bred sows during the winter. The ration fed was 1¼ pounds daily per hundredweight of sow, and alfalfa hay in a rack. One lot

[45] J. M. Evvard, O. W. Wallace, and C. C. Culbertson, Bul. 245, 1927.
[46] W. P. Snyder, Bul. 162, 1927.

was watered twice daily at the trough, while the other was supplied with a water tank where a lamp attachment kept the temperature of the water above freezing during the coldest weather and tepid most of the time. He concluded that there was *nothing in the results to* indicate that the self-waterer gave any better results than watering by hand twice a day at the trough.

IV *Care and Feeding of the Sow and Litter*

The foundation for a successful farrowing season is laid by proper feeding and care of the sows during the gestation and pregestation periods, but the number of pigs saved and finally raised is also a question of management and faithful attention to details during and immediately following farrowing. By following improved methods of feeding, housing, and care, the heavy preweaning losses can be materially reduced.

HOUSING AND CARE AT FARROWING TIME

Death losses in young pigs. The losses which occur among young pigs prior to weaning represent what probably is the heaviest drain on profits which the swine industry is forced to bear. The enormity of this loss has been shown by the survey studies made by the U.S. Department of Agriculture in cooperation with the Experiment Stations of Iowa, Illinois, and Indiana, as a part of its study of the cost of producing pork. A conservative interpretation of the data collected would place the loss which occurs up to weaning time between 30 and 35 pigs for each 100 farrowed. This mortality includes those pigs which are born dead. A further loss of 5 to 10 percent occurs after weaning, leaving only 60 percent of the pig crop to reach market.

The causes responsible for this heavy toll as reported by the observers, and the importance of each expressed in percentage of pigs farrowed, are shown in Table 15.

Close to one-half of the above losses are accounted for by those pigs which were laid on and crushed by their mothers. The next heaviest loss is represented by the pigs born dead or too weak to survive. But the important observation to be made here is that a majority of the factors responsible for the losses are to a large part under the control of the farmer and consequently many of the losses are preventable.

Table 15. Causes of Pig Losses before Weaning

Cause of Death	*Overlaid*	*Born Dead*	*Chilled*	*Born Weak*	*Starved*	*Eaten by Sow*	*Scours*	*Sore Mouth*	*Thumps and Worms*	*Injured by Other Stock*	*Lost*	*Smothered*	*Miscellaneous*	*Total*
Average percent of those farrowed	15.0	5.2	3.0	2.2	1.5	1.1	0.5	0.3	0.3	0.3	0.1	0.1	4.8	34.4

It should be profitable, therefore, to inquire further into these causes, to learn if possible what conditions back of them are immediately responsible. Below are listed briefly what might be called some of the probable causes.

Overlaid. The sow is deficient in the normal instincts of the mother, she does not lie down with the care always taken by the good mother, she is unconcerned when a pig squeals, and is careless; the sow is too fat, resulting in laziness, awkwardness, and lack of energy; the sow is deaf; the sow is cross, nervous, or irritable as the result of a bad disposition, improper handling or feeding, resulting in excessive activity; pigs are weak at birth and unable to get out of the way; pigs are anemic; quarters are unsuitable, having a lack of guardrails or hovers; too much loose straw is used for bedding.

Born dead. Too great a reliance on corn, *i.e.*, failure to supply the sow during the gestation period with a ration containing all the necessary food constituents and in balanced proportions, most commonly the result of insufficient proteins, calcium, vitamins, or iodine (lack causes hairlessness); overcrowding of the embryo pigs in the uterus of the mother as the result of an abnormally large litter or their uneven distribution; infection of the sow with the germs of contagious abortion; some accident or injury; weak germ cells which sometimes appear to result from inbreeding; ill-health of the sow.

Chilled. Failure to provide suitable facilities in cold weather; lack of care and attention.

Born weak. Pigs listed here died in the normal course of events and the causes responsible are the same as for those born dead.

Starved. The sow is naturally a poor milker; the sow has blind or inverted teats; the sow has more pigs than teats; an impoverished

condition of the mother, the result of starvation or incomplete rations; the pigs are born weak and unable to compete with litter-mates.

Eaten by sow. A craving on the part of the sow for flesh- and bone-forming food elements which her ration during pregnancy failed to supply; eating the afterbirth is believed by many to encourage the development of this vice.

Scours. Careless feeding, such as overfeeding the sow, especially during the first two weeks after farrowing; sudden changes in the sow's ration; feeding too much milk to the pigs, feeding it at irregular intervals, or at different degrees of sourness; insanitary lots and sour, dirty troughs; contagious diarrhea; damp beds; running in the wet grass; illness on the part of the sow; chill; anemia.

Sore mouths. Insanitary lots and filth-contaminated teats; injury or abrasion of the tissues of the lips or gums of the pig caused by fighting, teething, awns of grains, or irritating foods, making avenues for infection; infection with the germs of *Bacillus necrophorus* which causes "bullnose" or ulcerative sore mouth.

Thumps and worms. Until recently the chief cause of thumps was thought to be the combination of too much food and too little exercise. It is now believed to be generally the result of infestation with the common round worm, more particularly the presence in the lungs of the pig of the young worms when about one twenty-fifth of an inch long, which is the normal consequence of infestation. Severe anemia also causes thumps.

Injured by other stock. Inadequate lotting facilities; fences not pig-tight; lack of attention to details.

Lost. Same as for those injured by other stock.

Smothered. Generally the result of the same conditions which cause death from being laid on.

Distribution of pig mortality. It is important to note the distribution of these losses. Studies by Sevenson of the North Dakota Station [1] showed that of the mortality occurring from birth to weaning, 78 percent of the losses occurred during the first week. In a three-year study of baby-pig losses at the California Station [2] it was found that 75 percent of the fatalities occurred during the first two days. Records of the Purdue University Experimental herd,[3] covering the 24-year period from 1921 to 1944, of 1336 spring litters, showed an average of 9.8 pigs farrowed and 6.42 pigs alive at weaning time, a loss of 34.56

[1] Albert Sevenson, *Am. Soc. An. Prod. Proc.*, 1927.
[2] James R. Tavernetti and E. H. Hughes, Bul. 618, 1937.
[3] W. M. Beeson, *Mimeo. A. H.* 22, Sept., 1946.

percent, which included 5.16 percent stillborn. Fifty-two percent of these losses, not including those stillborn, occurred during the first three days; 15 percent was represented by those stillborn, 19 percent occurred from the fourth to the fourteenth day, and 14 percent from the fifteenth day to weaning time.

Davidson [4] reports an analysis made of the causes of preweaning losses in English herds by Menzies-Kitchin, in 1937. An average of 9.4 pigs were farrowed of which 7.7 were weaned. Complete causes of the death losses were obtained in 20 herds, as shown in Table 16.

Table 16. Analysis of Preweaning Mortality

Cause of Death	*Number*	*Percent*
Overlaid by sow	722	48.7
Bad doers	327	22.1
Scour (diarrhea)	135	9.1
Insufficient milk	119	8.0
Pneumonia and colds	77	5.2
Savaged by sow	28	1.9
Accident	20	1.3
Miscellaneous	42	2.8
Not recorded	13	0.9
Total number of observations	1483	100.0

High death rate due to pathological causes. That a high proportion of baby-pig losses is due to pathological causes rather than to accident or injury is indicated by post-mortem studies by Vestal and associates of the Indiana Station [5] of about 1000 young pigs which died or were purposely killed during the first week after birth. They report that the more common lesions observed were "(1) enlargement and fatty degeneration of the liver; (2) albuminous degeneration of the kidneys; (3) edema (puffy swelling of tissues); and sometimes an enlargement of the thyroid and adrenal glands. A relatively small number of the pigs showed evidence of injury due to being stepped on or laid on by the sows. In some instances marked precipitates (probably ureates) were present in the kidneys. These abnormalities apparently develop during embryonic life and not after the pigs are born." The inference to be made here is that these abnormalities are largely nutritional in origin.

"Baby-pig disease." The extent to which early pig losses may be attributed to the so-called "baby-pig disease," it is impossible to say.

[4] H. R. Davidson, *The Production and Marketing of Pigs*, Longmans, Green & Co., London, 1948, p. 426.

[5] C. M. Vestal, L. P. Doyle, L. M. Hutchings, F. N. Andrews, and W. M. Beeson, Mimeo. A. H. 22, Sept., 1946.

This malady, which has been responsible for nearly 100 percent losses in some herds, results in acute hypoglycemia, *i.e.*, an abnormally low sugar content of the blood. Typical symptoms have been reported as follows: "Shivering, dullness, and lack of desire to nurse; the pigs tend to wander away and burrow under the bedding; when disturbed they emit a weak 'graveyard' squeal; the hair stands upright, the skin is cold, and finally the pig lapses into a coma. Within 24 to 36 hours after the appearance of the first symptoms, several of the sick pigs in the litter are dead.[6] The disease is in no sense contagious. The fact that sows which have pigs which develop the disease may be rebred and produce normal litters, and that it is more common in spring-farrowed litters than those farrowed in the fall, suggests that it is in some manner related to the nutrition of the mother (see page 000).

Dr. Young of the Hormel Institute, University of Minnesota,[7] however, after extended investigation, concluded that baby-pig disease appears to be related to exposure of the pregnant mother to other diseases, especially during the last 20 to 40 days of the gestation period. His evidence indicated that nutrition, heredity, and environment did not play more than secondary roles in the disease.

Spring and fall losses compared. The figures given in Table 17 represent an interesting analysis by Steanson of the U.S. Department of Agriculture [8] showing the effect of the month and season on pig mortality before and after weaning.

The percentage of deaths prior to weaning was very much smaller for April- and May-farrowed pigs than for those dropped in February and March. The loss from weaning to market time, however, was heavier for the late pigs. The total proportionate losses up to marketing were greatest for the early farrowed pigs.

In the case of the fall pigs, it appears from these data that a larger percentage of October pigs have a chance to survive to weaning or market time than do August or September pigs, although fewer of the early farrowed fall pigs died after weaning. These figures indicate also that fewer fall pigs than spring pigs died prior to weaning, although the loss after weaning was sufficiently greater for the fall pigs, probably as a result of weather, to yield approximately the same percentage marketed.

[6] *Save Baby Pigs*, University of Illinois, Ext. Service, 1942.

[7] Geo. A. Young, Jr. and Norman R. Underdahl, Reprint, *The Cornell Veterinarian*, Vol. XXXVII, No. 3, July, 1947.

[8] Oscar Steanson, *Year Book of Agriculture*, 1928, p. 364.

Table 17. Farrowing and Death Records of Spring and Fall Litters

Farrowing Date	Number of Farm Records	Number of Pigs per Litter: Farrowed	Weaned	Raised to Market	Percent Deaths: Before Weaning	After Weaning	Raised
February	39	8.92	5.57	5.29	37.6	3.1	59.3
March	194	8.32	5.23	4.85	37.1	4.6	58.3
April	179	7.70	5.21	4.69	32.3	6.8	60.9
May	60	7.22	5.24	4.76	27.4	6.7	65.9
Average spring litters	472	7.91	5.25	4.80	33.6	5.7	60.7
August	52	8.42	5.66	5.16	32.8	5.9	61.3
September	108	8.24	5.66	4.82	31.3	10.2	58.5
October	31	7.90	5.89	5.16	25.4	9.3	65.3
Average fall litters	191	8.26	5.69	4.97	31.3	8.7	60.2

The most reasonable explanation for the decreasing size of the litters noted for those farrowed from February to May and from August to October is to be found, not in any effects of weather or

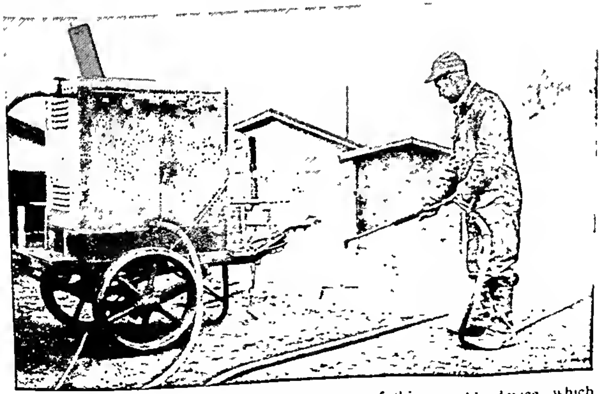

Fig. 11. Large operators will find the use of this portable device, which generates steam under pressure, an effective and practical method of disinfecting the farrowing quarters and other pieces of equipment *(courtesy, Drs W. E. Carroll and J. L. Krider, Ills. Exp. Sta.)*.

season, but rather in the variation of the breeding propensity existing among sows in general. Early farrowing sows as a class are more prolific than those farrowing late because the ability to farrow big litters and the tendency to come in heat promptly and to settle with the first service are related.

Preparation for farrowing. Timely preparations will do much to reduce farrowing losses. An important first step is to see that the farrowing pens are ready and properly equipped to take care of the litters in cold weather. First, they should be thoroughly cleaned and disinfected. To do this by the effective McLean County System (see page 89) the walls and floors are given a thorough scrubbing with boiling-hot lye water, using a stiff brush or old broom. One pound of lye should be used to 30 gallons of water. The lye will eat the organic matter out of the cracks and help to remove the caked mud from the walls and corners. A further precaution is to apply a 4 percent standard disinfectant, using a pump spray to force it into all the crevices and angles. Floor mats should be removed, washed, disinfected, and stood out in the sun. In case the floor is earth, 2 or 3 inches of the top layer should be removed, then replaced with fresh clay or fine cinders. Probably the most ideal floor is concrete covered with wood, but a good dirt or clay bottom is satisfactory if kept level, dry, and free from dust. Too often it is not. Bare concrete floors are cold and often become damp, unless they contain undersurface pipes for the circulation of hot water.

When the pens are thoroughly dry, they should be bedded carefully. The kind and amount of bedding to use is a matter of considerable importance. Any good absorbent that is dry and will lie close to the floor is satisfactory. Rye or wheat straw is preferred to oat straw. Cut straw, shredded stover, any fine-stemmed hay, sawdust or shavings, crushed corncobs, when available, are good because they interfere little with the efforts of the new-born pig to reach the mother's teat. A great pile of loose straw, although appealing to the natural instinct of the sow, is an evidence of mistaken kindness. As a rule, the less bedding used the better. Especially when the weather is not severe, a thin covering on the floor is sufficient.

The type of farrowing pen which seems best adapted to the weather and other conditions should be used. Depending on the size of the sow, the area of the pen desired normally should vary from a minimum of 6 by 7 to a maximum of 8 by 8 feet, inside dimensions. The installation of guardrails, about 8 inches from the floor and extending out

from the wall a distance of 10 inches, represented the first efforts of the hogman to reduce early pig losses. More extensive safeguards are illustrated in Fig. 12. This type of installation is especially adapted to individual farrowing houses situated in the open and where a source of artificial heat is not available. The two-by-fours rest on 10-inch boards which are nailed to the studdings. Behind this board straw is

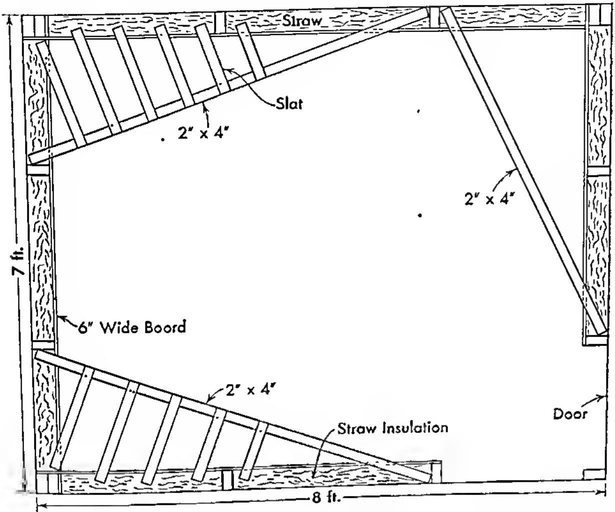

Fig. 12. This diagram illustrates a fixture in the farrowing house which is effective in saving the pigs where a source of artificial heat is not available. See text for description.

packed to the floor for insulation. By covering the slatted hovers with loose straw, and by banking the base of the house with cornstalks or straw, a practical arrangement is provided that has proved its worth on many northerly located hog farms. A gunny sack nailed to the top of the door and weighted at the bottom may also be used with good effect in keeping out the cold. After the second or third day, the pigs, except when nursing, will be found taking advantage of the warmth and safety of the hover.

Artificial heat helps to save young pigs. With early-spring pigs, especially in the North, a supply of artificial heat is necessary if chilling of the new-born pigs is to be avoided. An old stove or heater fixed up in one end of the central house is often the means of preventing chill. A lantern hung in the individual house will be an aid in the same direction. By putting the pigs as they are born into a straw-lined box or basket containing a jug of hot water or a hot brick, properly insulated, many pigs have been saved. Pigs suffering from chill can be revived quickly by immersing them in warm water, after which they should be dried and placed in a warm box.

Electrically heated pig brooders pay. The modern way, where electricity is available, is to equip the farrowing pen with a 100- or 150-watt reflector type of flood or heat lamp. By suspending the lamp

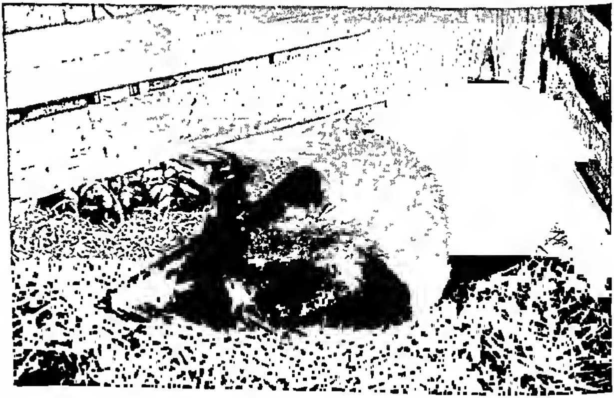

Fig. 13. A 150-watt heat lamp suspended in a partitioned corner of the farrowing pen ensures comfort and safety for the pigs *(courtesy, Ind. Exp. Sta., photo by Allen).*

over a partitioned corner of the pen at varying heights, depending on the weather, the pigs are safe and comfortable in the coldest weather. Additional heat can be secured when necessary by partially closing the top of the area and/or by boarding up a section of the front entrance.

From 1935 to 1939, Tavernetti and Hughes of the California Sta-

tion [9] compared two types of electrical heat installations. One consisted of an overhead electric light equipped with a reflector, and placed over a hole in the top of the brooder; the second was an underheat type, which consisted of an electrically heated metal pan or mat on which the pigs lie for warmth. A third group of sows farrowed in pens equipped with brooders but without heat.

The results of the three-year trials showed that the pig losses in the pens equipped with heated brooders were approximately one-half what they were in the unheated pens. There was practically no difference in the results obtained with the two types of heating, the losses being 13 and 15 percent. In the regular farrowing pens the losses were 29 percent. Unusual difficulty was reported in getting the pigs to take advantage of the unlighted and unheated hovers. In the heated brooders, the time required to teach them to go in varied from a few hours to a day or more. The experimenters concluded that the overhead source of heat was to be preferred to the underheat plan, because "it was simpler, less expensive and easier to construct; the light attracted the pigs and illuminated the pen; there was less danger from electric shock; and the amount of heat could be varied by changing the size of the light globes." Some trouble was experienced with the metal brooders becoming too warm for the pigs' comfort. A preference was expressed in favor of the 150-watt lamp as compared with the 100-watt, although both were considered satisfactory.

The value of electrically heated pig hovers or brooders for early spring farrowing was further demonstrated in a three-year study by Foster and Vestal of the Indiana Station.[10] Including the records on three cooperating farms, 64 sows farrowed in individual houses equipped with brooders heated with 100- or 150-watt lamps, and 41 farrowed in similar houses containing corner hovers but without heat. The losses during the 10-day observation period following birth averaged 16.9 percent in the houses equipped with lamps and 34.3 percent in the houses without the lamps. The difference amounted to one and one-half pigs to the litter. Since there were causes other than the heat factor responsible for many of these losses, it was estimated that the fatalities due to chilling alone amounted to 2.2 percent of the pigs farrowed in the houses equipped with supplemental heat, and 10 percent in the houses without the heat.

The important observation was made that death losses in the un-

[9] James R. Tavernetti and E. H. Hughes, Bul. 618, 1937.
[10] G. H. Foster and C. M. Vestal, Bul. 494, 1944.

heated houses progressively increased as the outside temperature went down. On the other hand, it was found that the outside temperature had little if any effect on losses when supplemental heat was supplied. Temperatures under the unheated hovers varied with like changes in the outside temperatures, as one would expect; under the heated hovers, the temperatures approximated 30°F higher than on the outside. These records were taken when few if any pigs were in the hovers. The presence of a large litter of week-old pigs was found to maintain a temperature in an unheated hover (with covered top and partly closed front) 50 to 60 degrees above the outside temperature in cold weather. The records showed that the pigs did not use the unheated hovers during the first two days, and only infrequently during the next four or five days, a fact that emphasized the need of supplemental heat during the critical first few days after birth, and also the ministrations of a careful attendant.

Depending on conditions, such as the distance of the farrowing houses from the source of electricity, the length of time used, and the number of litters farrowed in each heat-equipped house, these authors concluded that the total cost should not exceed two dollars for each litter farrowed.

Temperature drop in new-born pigs. The need for close personal attention to the heat requirements of new-born pigs is further emphasized by important studies made by Newland and associates of the Michigan Station.[11] They found an average temperature drop of 4°F during the first hour following birth among 25 pigs farrowed in a central barn where the temperature varied from 65 to 70°F. The drop ranged from 3 to 9°. The sharpest drop occurred during the first 20 minutes after birth. After the pigs were an hour old, there was a gradual rise to normal. Twenty minutes after birth the average temperature was 100.5°; at 10 hours it was 101.5°; at 24 hours, 102.3°; and at 48 hours, 102.5°, the temperature of the mothers. The lightweight pigs (under 2 pounds) showed a sharper drop in temperature and a slower rise to normal than did the heavier pigs.

The crate system of farrowing. H. E. Hawley of Dawson Creek, British Columbia, where winter temperatures often go below −60°F, reports the saving of two extra pigs to the litter by the use of the crate system of farrowing. With 200 sows he has produced annually during the past 10 years 3000 weanling pigs for farmers and feeders in his

[11] H. W. Newland, D. P. Wallace, and W. N. McMillen, *Jr. An. Sci. Abs.*, Vol. VII, No. 4, 1948.

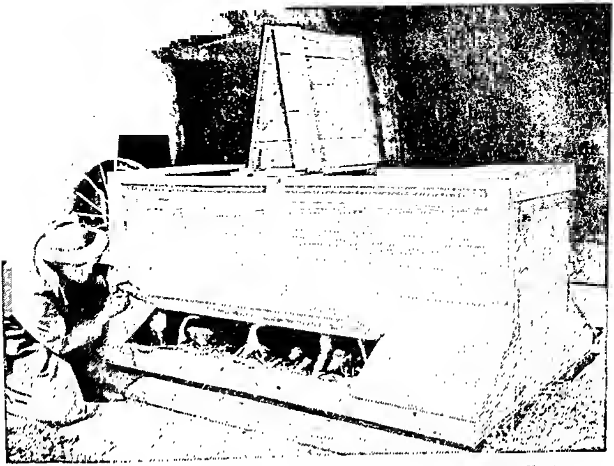

Fig. 14. The enclosed type of farrowing crate *(photo by Allen).*

area. The sows are placed in crates similar to the type shown in Fig. 14 the day before they are due, where they remain for two weeks after farrowing; then they and their litters are removed to double pens inside the double-deck central barn where they remain until weaning time.[12] The more usual practice in the Corn Belt, however, is to remove the sow and litter from the crate two to four days after farrowing. Also, during this period, the sow is allowed outside daily for a little change and exercise.

This plan, which is considered by many as an innovation, was observed by the author in use on the farm of the late A. J. Lovejoy more than 35 years ago. Reference is made by Davidson [13] to its use in England and Denmark. That there has been recently a marked interest in the idea is indicated by its adoption in various ways on many hog farms of the Corn Belt during the past few years. Its value lies in the fact that the sow cannot turn, and a safe retreat and a hover for warmth are provided on either side for the pigs. The most popular

[12] *The Country Gentleman*, Jan., 1948.
[13] H. R. Davidson, *The Production and Marketing of Pigs*, Longmans, Green & Co., London, 1948, p. 340.

adaptation of the idea is that of installing a removable built-in crate in the individual farrowing house, as shown in Fig. 15. A few of these houses so equipped, and conveniently located inside the barn or closed shed, may be used for farrowing the entire herd.

The success of this method of handling sows at farrowing time would seem to depend on how it is used and what is expected of it. The claim that it offers safeguards against injury and crushing of the young pigs seems well established. On the other hand, that it does away with the need of personal attention at farrowing time is not well founded. This assumption is responsible for many of its reported failures.

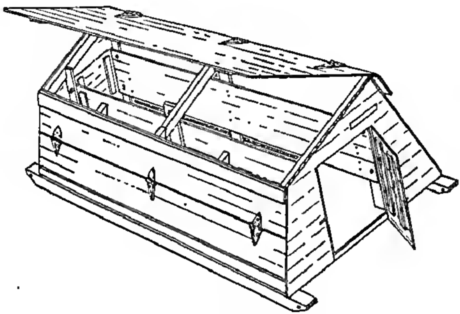

Fig. 15. A removable built-in farrowing crate *(courtesy, Agr. Eng. Dept., Ind. Exp. Sta.).*

Experience has revealed a number of difficulties in its successful use. In the first place, the sow offers resistance against entering the crate, which often results in some rough handling; after she is in, she does not take kindly to the unnatural confinement. Especially in the tight box-like crate shown in Fig. 14, she becomes worried and ill at ease. Under these stresses a nervous sow sometimes goes berserk and chews up the fixtures or demolishes them entirely. She finds it difficult to get up from a reclining position, and too often in practice her bed becomes wet and filthy. By careful handling, however, many of these difficulties can be overcome. A number of good hogmen have given the plan enthusiastic endorsement, while others, after trial, have discontinued its use.

Tilted floors in the farrowing house. Raising one side of the farrowing house about 1 foot, or locating the house on a hillside, to give a slope to the floor represents a device for saving young pigs from crushing that has a number of advocates. The claim is that the sow generally will lie with her back uphill, thus presenting the pigs with a more direct and easy approach from their bed for nursing. Also, less time usually is required for the pigs to learn the use of the hover, which is situated on the lower side. Pifer of the Kentucky Station [14] reports from tests and observation on 385 litters kept on 49 farms that sows farrowing on tilted floors lost only 3⅓ percent of those farrowed from crushing, while on the level floors the sows lost nearly 25 percent from the same cause.

Preliminary care and feeding. Before being placed in her farrowing pen the sow should have her sides, udders, and under surface of her body washed with warm soapy water. The purpose of this is to remove any adhering mud or filth which might harbor disease germs and especially the eggs of the common roundworm. She should be kept absolutely clean. The last ministration before farrowing should be a sponging off of the udders. This precaution is one of the essential steps in the plan designed to prevent worm infestation, and the practical importance of it has been repeatedly demonstrated.

The sow should be removed from the general herd a few days before she is expected to pig. This will enable her to become acquainted with her new quarters and will serve to make her more contented when pigging. By this procedure she will also become accustomed to the presence of the herdsman, which is important later in the care of herself and her litter. An effective way to quiet a nervous sow is to give her a daily brushing. The sow should be removed from the general quarters no later than the one hundred and tenth day of gestation.

Farrowing Record

Number of Sow	*Date of Service*	*Date Due*	*Date Farrowed*	*Number and Sex of Pigs*	*Ear-notch Number*
51	Nov. 10	Mar. 2			
36	Nov. 12	Mar. 4			
etc.					

[14] R. W. Pifer, Leaflet 95, 1945.

The importance of a record of the date of service is apparent at this time, as it is impossible to tell with any reliable degree of accuracy by the appearance of a sow just when she will pig. The usual signs of approaching farrow are a filling of the udder and teats and a mild spirit of unrest. When the sow begins carrying litter or arranging her bed for a nest, she may be expected to farrow within 12 hours. Without a record, constant observation of the sows is imperative, and even with such a record it is still desirable. A farrowing sheet should be made out and posted in a convenient place in the barn. This should contain the number, date of service, and the date due, of each sow in the herd, with blank spaces for recording the date of farrowing, the number and sex of the pigs, and the ear-notch number of each litter.

Opportunity for some exercise should be given the sow after she has been removed to the farrowing pen, but care should be taken that any dirt or filth which may have become attached to the udders be removed before she is returned. It too frequently happens that she is shut in a pen with no liberty to move about. This is certain to aggravate the tendency to constipation as well as to make it difficult to keep her quarters in a dry sanitary condition. If a lot is not accessible to the farrowing pen, the sows that are up should be turned together in a clean open yard for a part of the day to work over some clover or alfalfa hay.

It is very important that the ration of the sow be carefully regulated in the days just preceding farrowing. Two important changes should be made in her feeding; *the ration should be made more laxative and* the amount fed reduced. She will need less food under the more restricted conditions, and her recovery from farrowing will be more prompt if her digestive system is kept well cleared. Any tendency to constipation is dangerous. By feeding with the grain a quantity of wheat bran or linseed-oil meal, her droppings will be kept in proper condition. A safe rule to follow at this time is to cut her grain ration in half and add to it one-half its bulk in wheat bran. One pound, or about a quart, of this mixture to the feed just before farrowing is sufficient.

Care at farrowing time. The previous treatment of the sow will determine largely the results at farrowing time. If she has taken plenty of exercise during the preceding months, has been fed properly, and is in a strong active condition, she will cause little concern. With all preparations made, the attitude of the man in charge should be that of "watchful waiting." With a large number of sows to farrow, he

should be at his post constantly during the day and every three hours at night, especially if the weather is severe.

The quiet presence of the attendant is desirable when the sow is farrowing. He should assist the new-born pig in its efforts to free itself from the enveloping membrane and to start respiration. The next step is to place the pig where it is warm (see page 76). When farrowing has been completed, the pigs should be given the opportunity to nurse. The instinct to nurse should be satisfied as soon after birth as possible. Pigs that are weak should be assisted or held to the teat. The first milk of the mother acts as a purgative, initiating the functions of digestion and ensuring the expulsion of the accumulations of the digestive tract. It also has the effect of immunizing the pig temporarily against the development of certain germ infections.

It is particularly important during the first week to see to it that each pig is getting its due share of nourishment. The milking capacity of the sow should be observed carefully and, if there are more pigs than good teats, the stronger ones should be transplanted to another sow with more teats than pigs and whose litter is as nearly as possible the same age. The transfer accomplishes two important results: it secures needed nourishment for the extra pigs in the large litter and

Fig. 16. Pigs from a sow with more pigs than good teats can with advantage be transplanted to another sow with more good teats than pigs [illegible]

ensures a better development of the udders of the sow which is nursing a limited number of pigs.

Gilts that are not in good breeding condition frequently have trouble in giving birth to their pigs. As soon as it is evident that protracted labor is of no avail, help should be given. A small hand and arm, which have been thoroughly cleaned and smeared with Vaseline, is the best instrument. The unskillful use of pig extractors is usually unsuccessful and often a cause of injury to the organs of the sow. Without some knowledge of the position of the organs and foetuses, she should have the attention of a veterinarian.

The afterbirth should be removed as soon as the sow has cleaned and be burned or buried. If it is allowed to remain in the pen she may eat it, which is believed by many to encourage the development of the pig-eating vice. Dead pigs should be removed promptly for the same reason. A few days after farrowing, the pen should be cleaned and fresh litter supplied. Air-slacked lime scattered on the floor has a cleansing and drying effect.

Some interesting observations. Systematic observation and record taking of the nursing period have revealed some interesting facts.

A mature sow will lose from 35 to 50 pounds in weight in farrowing. About 64 percent of this loss is represented by the pigs, 25 percent by the amniotic fluids and products of metabolism, and 11 percent by the placental membranes or afterbirth. The average time required to "clean" is 2 hours, the longest 3 and the shortest 1 hour (see page 31).[15] The fatter the sow, the greater will be the loss, as a rule; the principal factor, however, is the number of pigs in the litter.

The average time required for 23 sows to farrow was 4 hours and 19 minutes, the longest 18 hours, and the shortest 53 minutes. S. Berg[16] reports observations in which the farrowing time varied from 2.68 to 4.07 hours with an average of 3.5 hours.

Purdue studies of two litters indicated that the four front teats are the heaviest producers and that generally these are nursed by the larger stronger pigs. Donald of Edinburgh University[17] in a study of the milk consumption and growth of nursing pigs reports the interesting data shown in Table 18.

There were 10 pigs in this litter. The figures represent the milk obtained from each teat for an average day during the test period of

[15] Purdue University thesis studies, 1915, 1928, 1930, and 1931.
[16] U.S.D.A. *Exp. Sta. Record Abs.*, Vol. 84, 1941.
[17] H. P. Donald, *Empire Jr. of Exp. Agr.*, Vol. V, No. 20, 1937.

Table 18. Milk Obtained from Each Teat by Nursing Pigs

Teat Pair Number	*1*	*2*	*3*	*4*	*5*	*6*
	gm.	gm.	gm.	gm.	gm.	gm.
Right side	4381	4480	2373	4334	3717	2707
Left side	5201	3169	4862	2572		
Totals	9581	7649	7235	6906	3717	2707

one week, and were determined by keeping the sow and litter separated, and weighing the individual pigs immediately before and after each nursing. The total milk production was equivalent approximately to 7½ pounds daily. Each pig nursed its own particular teat, except that the two rear pairs were nursed by two pigs.

That each pig tends to nurse a special teat is borne out by these observations. The first week after birth is apparently a period of adjustments, during which time the individual pigs compete for the better teats. As a rule, the number of teats which continue in milk during the nursing period does not exceed the number of pigs in the litter. The growth made by the individual pig during the first three weeks of life would seem to be limited, therefore, by the amount of milk secreted by the particular udder or teat nursed.

Carlyle of the Wisconsin Station [18] is the authority for the observation that new-born pigs nurse very irregularly at first but soon settle down to a regular schedule, which is every two hours during the day and four hours during the night. He also observed that the length of time between nursings did not lengthen as the pigs grew older. Herdsman Geiken of the North Dakota Station [19] took daylight observations on the frequency of nursings of five litters on different days during the first three weeks after birth. The average time for the interval between nursings was 70 minutes, the shortest 15 minutes and the longest 3 hours and 15 minutes. There was no tendency apparent for the interval to lengthen within this period as the pigs grew older. Newlander and Jones of the Vermont Station [20] report an average interval between nursings, both night and day, of 50.5 minutes.

Needle teeth should be removed. An examination of the mouth of pigs at birth will show that they have the needle, or black, teeth. Their

[18] W. J. Carlyle, Bul. 104, 1903.
[19] J. H. Shepperd, Bul. 230, 1929.
[20] J. A. Newlander and C. H. Jones, Bul. 389, 1935.

Fig. 17. Showing "needle teeth" of pig at birth.

appearance is shown in Fig. 17. These teeth are normal, inclined to flatness, have sharp edges, and generally are brown in tinge at the tip. Needle teeth often are the cause of irritation and pain to the sow when the pigs nurse, especially at first when the udders are tender. Considerable laceration of the lips and gums of the pigs also is often incurred by fighting. These cuts or abrasions may become infected and a sore mouth may result. Hogmen who give their pigs most attention believe, as a rule, in removing these teeth immediately after birth. This should be done carefully by cutting close to the gum with forceps made for the purpose.

Ear-notching the litters. In pedigreed herds it is necessary to give each pig an identification mark so that the parentage of each can be determined later by reference to the herd record. In herds kept exclusively for the production of market pork, such records are desirable to make more certain that the gilts retained for the breeding herd are selected from the large litters and good mothers. The scheme universally employed for this identification is some system of ear notches made with a special ear marker or ordinary harness punch. All pigs in the litter are given the same litter mark. According to this plan, the first litter farrowed is given one notch in the outer right ear; the second litter, one notch in the outer left ear; the third two notches in the right ear, etc., as follows:

1st litter—1 notch outer right ear
2nd " —1 notch outer left ear
3rd " —2 notches outer right ear
4th " —2 notches outer left ear
5th " —1 notch outer right and 1 outer left ear
6th " —2 notches outer right and 1 outer left ear
7th " —2 notches outer left and 1 outer right ear
8th " —2 notches outer right and 2 outer left ear

9th " —1 notch inner right ear
10th " —1 notch inner left ear
11th " —1 notch inner right and 1 outer right ear
12th litter—1 notch inner left and 1 outer left ear
13th " —1 notch inner right and 1 outer left ear
14th " —1 notch inner left and 1 outer right ear
15th " —1 notch inner right and 2 outer right ear
16th " —1 notch inner left and 2 outer left ear
17th " —1 notch inner right and 2 outer left ear
18th " —1 notch inner left and 2 outer right ear
19th " —3 notches outer right ear
20th " —3 notches outer left ear.

A second plan is suggested by A. J. Lovejoy in his book *Forty Years' Experience of a Practical Hog Man.* According to this plan each notch in the outer right ear counts one, each notch in the outer left ear three, each notch in the inner right ear ten, and each notch in the inner left ear thirty, as illustrated in Fig. 18a.

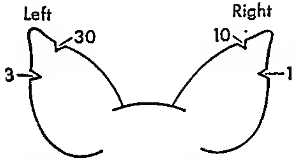

Fig. 18a. Key to second plan of ear-notching.

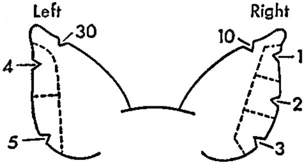

Fig. 18b. Key to third plan of ear-notching.

In this scheme the number of the litter is determined by adding the figures for which the notches stand. For example, one notch in the outer right ear would be litter number 1, while two notches in the outer right would be litter 2 (1 + 1). Two notches in the outer left would be litter number 6 (3 + 3), and two in the outer right and one in the outer left would be number 5 (1 + 1 + 3). Litter number 47 could be shown by one in the inner right, one in the inner left, one in the outer right, and two in the outer left, etc. This plan of marking is well adapted to herds where the number of litters exceed 30 or 40.

A third plan of marking is illustrated in Fig. 18b. By this scheme the number of the litter is determined by the position of the notch on the ear. The outer rim of the right ear is divided into three areas, numbered 1, 2, 3, from the forward point of the ear back. A notch in the forward third of the ear would stand for litter number 1, a notch in the center would be number 2, while one well back in the third area would be number 3. The outer left ear is divided into two areas, num-

bered 4 and 5, from front to back. A notch in the forward rim of the left ear would be litter number 4 and one in the fifth area would be number 5. Each notch in the inner right ear stands for 10, and each in the inner left 30, regardless of their position.

The number of notches required in this system is reduced to a minimum. Ninety litters can be numbered without necessitating more than two notches in either rim of each ear. In using this system it is important that the position of each notch be carefully located, especially those in the outer right ear, else they may be misread.

Feeding just after farrowing. After farrowing, the sow is in a feverish state and will neither want nor should be offered feed for 24 hours. She should be given plenty of fresh water, however. Special care should be taken in her feeding the first week. The promptness of her recovery and the success with which she comes to her milk flow will be influenced largely by the judgment used. The same type of ration should be fed just after farrowing as was used before. Rather thin slops of meal containing little or no corn will give the best results. A supply of shorts, bran, and ground oats or barley is excellent to have on hand at this time.

A safe procedure to follow the first week after farrowing, and one that has given good results in practice, is the following: The first day give the sow plenty of water but no feed; the second and third days give her one small double handful of meal each feed (one double handful of meal containing the desirable proportion of bran and shorts will weigh about half a pound); the fourth and fifth days after farrowing give her two double handfuls each feed; the sixth and seventh days, three double handfuls for each feed.

Beginning with the second week after farrowing, the ration should be gradually increased at the rate of one-half to one pound daily until she is on full feed. During the second week also the proportion of bran should be reduced and the ration gradually changed to incorporate those feeds to be fed during the nursing period. It is important to remember at this time that too much haste in bringing the sow up to full feed often results in digestive disorders for the sow, scours in the pigs, and loss of milk later.

Exercise and sunshine are important. Getting the pigs out on clean pasture is desirable for the reason that it supplies the conditions which encourage exercise in the open. For young animals, generally, to restrict the opportunity for exercise is to deny them the privilege for normal development. Early-spring or late-autumn pigs, when confined to a central house, should be given the liberty of the alley for a large

part of the day in order that they may get this needed exercise, especially when the weather is bad. Fragments of paper scattered about or a pile of loose straw or leaves will have the effect of stimulating play.

Pigs must also have the opportunity to lie in the sun. Like plants, pigs will not thrive in the dark. Recent studies in nutrition have established the fact that a close relationship exists between the ultraviolet, or short, rays of the sun and the growth vigor displayed by young animals, especially affecting the growth of the bones. Rachitis is likely to develop among pigs deprived of sunshine when the mother's diet at the time, and during the previous gestation period, is deficient in vitamin D (see page 58).

THE McLEAN COUNTY SYSTEM OF SWINE SANITATION

The McLean County System of Swine Sanitation was developed by Drs. Ransom and Raffensperger of the U.S. Bureau of Animal Industry, after years of research, and its practicability tested on 30 cooperating farms in McLean County, Illinois, during a period of seven years, commencing in 1919. Although designed specifically to prevent infestation of young pigs with the common roundworm (Ascaris lumbricoides or Ascaris suum) the system, if faithfully followed, will reduce the loss from other parasites, such as the thorn-headed worm, mange, lice, and filth-borne diseases such as canker sore mouth or bullnose, necrotic enteritis, and some forms of diarrhea. Also, pigs so managed will rarely become anemic.

How the system is applied. There are three steps involved in the plan, the first of which has already been referred to (see page 74), as follows:

1. Clean the farrowing quarters thoroughly and then scrub with boiling water, adding one pound of lye to 30 gallons of water.
2. Brush all loose litter and mud from the sides of the sow; then wash the udders thoroughly with warm water and soap, and then place the sow in the clean farrowing pen. This is done three or four days before farrowing.
3. Confine the sow and pigs to the farrowing pens until they are removed to a clean pasture, and haul—do not drive—them to the pasture. Water and feed must be provided in the clean pasture, as the young pigs must not, under any circumstances, be permitted to go back to the permanent hog lot for feed or water until four months old.[21]

A clean pasture is a field that has grown a crop since last occupied by hogs, or a pasture that has not had hogs on it for at least one and

[21] H. B. Raffensperger and J. W. Connelly. U.S D.A., Tech. [illegible] 44, 1927

preferably two years. In order to avoid anemia, the time the sow and litter should be allowed to remain in the farrowing house before being hauled to the clean pasture, weather permitting, should not exceed one week.

Most hogs have worms. According to Ransom [22] one out of every three mature hogs harbors worms. One of these female worms may contain the astonishing number of 27 million eggs. As the eggs are liberated, they pass out with the feces. The soil of much-used hog lots consequently is usually heavily infested. When passed out in the feces the eggs are in the dormant, or noninfectious, stage. It is only after they have developed embryos that they become dangerous. Under the most favorable weather conditions, *i.e.*, when it is warm and moist,

Fig. 19. Roundworms (*Ascaris lumbricoides*). This common intestinal parasite when present in large numbers takes a heavy toll in unthriftiness.

the eggs may develop from the dormant to the infectious stage in the short time of two to three weeks. Eggs discharged in early March, however, probably will not find the conditions sufficiently favorable in the central Corn Belt to enable them to reach the embryo or infective stage before six to eight weeks have elapsed. In a cool dry place they will remain in the latent or dormant condition for years. They are very resistant to low temperatures. Just how long they will live in old hog lots and in the manure about straw stacks is not known exactly; that they generally survive our winters, however, is certain.

[22] B. H. Ransom, U.S.D.A., Leaflet No. 5, 1921.

Ordinary disinfectants do not kill them. Direct sunlight and scalding water are the two agents most certain to destroy them.[23]

Worms mean unthrifty pigs. The practical damage done by the common round worm is expressed in various degrees of unthriftiness, by difficult breathing and "thumps," and by pneumonia. These are the symptoms which largely are the direct result of the invasion of the lung tissues by the migrating larvae or tiny worms. Thumps have been experimentally produced by infecting young pigs with worms, and the affliction shown to be similar in every particular to the kind commonly observed in the field. Pus infections and abscesses of the lungs also may follow. Many pigs die if the lung infestation is heavy; if the infestation is light there may be no evidence of respiratory trouble. By the time the worms reach a development in the small intestines to make the administration of worm expellers of any use, most of the damage probably has been done.

The accumulation of the mature worms in the small intestines of the young pig, however, seriously interferes with the digestion and the free passage of the food along the intestinal tract. Clumps of worms may form which completely obstruct the passage. They also levy a heavy toll on the pig's food supply. Pigs heavily infested suffer from intermittent scours or diarrhea. The worms have been known to invade the gall bladder and ducts. The migration of the larvae through the liver undoubtedly interferes with the work of that important organ. The younger the pig, the greater is the damage resulting from worm infestation. Pigs which are partly grown and are liberally fed on good rations, on the other hand, may harbor some worms without suffering any apparent injury (see Chap. XXII).

NUTRITIONAL ANEMIA

Pigs which are farrowed early in the spring or in late autumn, or are confined indoors for a period longer than one week after birth almost invariably become anemic. Under these conditions they become dull and listless, the skin pale and wrinkled, the hair stands on end, and the ears and tail droop. In severe or advanced cases the skin becomes thick and puffy in appearance, the breathing pumping or spasmodic in character, which may end with respiratory convulsions and death. Post-mortem examination reveals a great dilation of the heart, a degenerated fatty liver, pale viscera, and excessive quantities of thoracic and abdominal fluids.[24]

[23] Robt. Graham and I. B. Boughton, Ill. Exp. Sta., Cir. 269, 1923.
[24] L. P. Doyle, F. P. Mathews, and R. A. Whiting, Ind. Exp. Sta.

Fig. 20. Anemic pigs, the result of being confined the first three weeks after birth *(courtesy, Ind. Exp. Sta.)*.

Anemic pigs lack sufficient red blood. Nutritional anemia is a disease associated with, or the result of, a depleted supply of hemoglobin (red coloring matter) in the pig's blood. Hemoglobin is the oxygen-carrying substance of the red blood cells. In the formation of hemoglobin, the elements iron and copper must be present. Sow's milk, like that of most other species, is deficient in iron. Unlike the young of most other species, however, the pig either is not born with a reserve store of iron in his liver and spleen sufficient to tide him over the period during which he is dependent solely on the mother's milk, or his capacity for growth is so great that his body reserves of iron are exhausted before the opportunity to supplement the milk diet with solid foods is reached.

As a result of this deficiency in the mother's milk, a rapid decline in the number of red blood cells and the hemoglobin content of the blood normally takes place during the first three weeks of the life of the suckling pig. Three weeks after birth this depletion has usually reached a point where the content is no more than one-half the concentration at birth. This is a critical period, for if regeneration in the supply of red blood does not begin at once, or soon after, severe anemia results.

Methods of prevention and cure. Extensive investigations of anemia have been made at the Indiana, Illinois, Wisconsin, and other Stations. A summary of these studies points rather definitely to the following conclusions and recommendations for its prevention and cure.

The disease cannot be prevented or cured by any known treatment or method of feeding the mother before or after farrowing. When confined indoors for more than a week a majority of the pigs in the litter will become severely anemic.

Several methods of prevention have more or less successfully been used for confined pigs. (1) Spraying or swabbing the udders of the sow once or twice daily with a saturated solution of copperas (ferrous sulphate), made by dissolving half a pound of finely ground crystals in one quart of water, has given good results. Sufficient copper is found along with commercial copperas ordinarily to make the addition of this salt unnecessary. (2) Keeping in one corner of the pen a square of fresh sod or a shovel of clean soil for the pigs to root in has been favorably reported on by farmers and investigators. If this soil is sprayed daily with a copperas solution, prevention will be more certain. (3) Dosing the pigs individually with the copperas solution has been proved most effective, but rather bothersome.

A method of prevention tested and recommended by Professor R. G. Knox of the Ontario Agricultural College is that of placing a pinch of finely ground copperas crystals between the lip and gums of the pigs two or three times weekly. This appears to be the most effective and practical treatment thus far recommended for confined pigs.

When the litter is confined for a week or less and can then be placed outside in contact with clean soil, severe anemia does not develop.

Finally, there should be added the important observation that, although a pig with severe anemia may have the hemoglobin and blood count restored by appropriate treatment, the effect of the disease on some of the vital organs is often such that it suffers injury from which it never completely recovers.

FEEDING THE SOW AND LITTER

The vigor and rate of development of the pigs from birth to weaning time will depend largely on their supply of good food. First in importance in providing this nourishment is the mother's milk, especially for the first month after birth; and second, the supply of appropriate dry feeds to supplement it during the latter half of the nursing period.

The pig-creep. When two or three weeks old, the pigs begin to take an interest in their mother's rations. This interest should be encouraged, for pigs of this age have the teeth and digestive apparatus successfully to use small quantities of solid food. The sow produces her

maximum flow of milk on the average three weeks after the pigs are farrowed, and from this time on, the decreasing supply must be supplemented to meet the needs of the pigs whose feed requirements are increasing with each day.

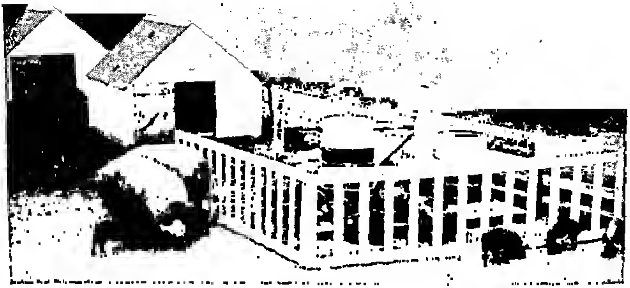

Fig. 21. A good type of pig creep, properly equipped. Note the home-made self-feeder and waterer and the raised platforms. In the feeder is a mixture of four parts cracked corn, one part cracked wheat, with 10 percent of a supplement of protein and minerals.

The pigs, however, should not be required to take their chances at the trough with the sow, especially when several sows and litters are together. They get little feed and often come out of the scramble permanently crippled. A creep is desirable also because the limited digestive capacity of the pig prompts him to eat frequently. His extraordinary capacity for growth can be satisfied only when his feedings are not too far apart.

As a guide in making up palatable rations for young pigs, it will be of interest to note their choice of feeds when offered a variety, in free-choice style. Carroll of the Illinois Station [25] performed such an experiment with two groups of nursing pigs in the spring of 1930. In Table 19 the amount of each feed eaten, expressed as a percentage of the total feed consumed, is shown. The most outstanding characteristic of these figures shows the decided preference of the pigs for the whole as compared with the ground grains and their dislike, generally, of feeds containing much fiber.

In an *interesting experiment* at the Minnesota Station Ferrin and

[25] W. E. Carroll, A. H. Mimeo. 315, 1935.

Table 19. Palatability of Feeds for Sucking Pigs

	Group 1	*Group 2*
Number of pigs	96	71
Average age of pigs at start (days)	39	46
Days on test	41	28
Shelled corn consumed	39%	38%
Coarsely ground corn consumed	7%	4%
Wheat middlings consumed	0%	1%
Steel-cut oats consumed	35%	45%
Ground oats consumed	0%	0%
Hulless oats consumed	10%	0%
Ground hulless oats consumed	2%	0%
Supplement consumed	7%	11%

associates [26] compared skim milk and tankage as supplements to a ration of yellow shelled corn and red dog flour for fall-farrowed suckling pigs, the test period beginning as soon as the pigs had learned to eat dry feed and continuing to weaning time. The corn was fed separate and dry, while the skim milk and tankage were mixed with the red dog in their respective lots and fed as a slop. A third group of pigs was given the corn and red dog without an additional supplement. The pigs in all three lots had access to green rye and received twice a week a mineral mixture supplied in the slop. The pigs, 18 or 19 in each group, were 30 days old when the test began on October 20. The summarized results are shown in Table 20.

Table 20. Skim Milk and Tankage for Nursing Pigs

Rations	*Initial Weight*	*Final Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.		lb.
Shelled corn + red dog flour + skim milk	17	35	0.757	Corn	66
				Red dog	17
				Skim milk	166
Shelled corn + red dog flour + tankage	14	28	0.555	Corn	59
				Red dog	17
				Tankage	7.87
Shelled corn + red dog flour	14	25	0.451	Corn	74
				Red dog	40

The results indicate that nursing pigs will make profitable use of a protein-rich supplement along with grain. The gains made by the pigs

[26] E. F. Ferrin, M. A. McCarty, and C. R. Carlson, A. H. Mimeo. H-17, 1924.

getting tankage were good, while for those receiving the skim milk they were exceptional.

Some creep rations. Following are some creep rations that have given good results:

1. Four parts cracked corn + 1 part cracked wheat + 1 part tankage, mixed together and self-fed.
2. Four parts cracked corn or ground barley + 1 part wheat middlings + 1 part tankage, mixed together and self-fed.
3. Shelled corn and hulless oats, or ground oats with the hulls sifted out, self-fed, free-choice + skim milk or buttermilk, hand-fed.
4. Shelled corn, self-fed + skim milk or buttermilk, hand-fed.
5. Three parts cracked corn + 1 part red dog flour, mixed together and self-fed + skim milk or buttermilk, hand-fed.
6. Shelled corn, self-fed + a slop of 1 part flour middlings or red dog flour and 4 parts skim milk or buttermilk, hand-fed three times daily.
7. Rolled oats, self-fed.

Weaver of the Missouri Station [27] suggests the following ration: Two parts shelled or preferably ground corn and one part of a mixture made up of equal parts wheat shorts, tankage (or meat scraps), soybean oil meal (or linseed or cottonseed meal), and choice quality alfalfa meal (if on good pasture omit the alfalfa). Also self-feed a mineral mixture of equal parts finely ground limestone, bone meal, and salt.

The practice of supplying the nursing pigs, after they are four weeks old, with a dilute solution of semisolid buttermilk for drink has been favorably reported on by a number of good hogmen. From 15 to 20 parts of water are used with one part of the semisolid product.

For best results in thrift and gains, these young pigs must be fed carefully. In hand-feeding a slop of milk by-products, it is particularly important that no more be given at one time than will be cleaned up promptly. When hand-fed, they should be given small amounts and often, say, four or five times a day. The self-feeder, when used, should be carefully adjusted and the trough frequently cleaned. These precautions are important in eliminating one of the common causes of scours.

[27] L. A. Weaver, Cir. 250, 1943.

Antibiotics stimulate growth of nursing pigs. Carpenter of the Hormel Institute [28] reports that the addition of APF (Lederle's No. 5) concentrate to the creep ration of rolled oats, at the rate of 1 percent, increased the weaning weight by the difference between 25 and 36 pounds compared with those receiving rolled oats alone. Feeding the dams during lactation an APF concentrate containing aureomycin at the rate of 0.5 percent of the ration had no effect on the weaning weights, indicating no transfer of the antibiotic to the pigs through the milk. In further studies he determined that the addition of 2 grams of pure aureomycin to 100 pounds of rolled oats in the creep ration increased the weaning weight over the control pigs from 22 to 33 pounds. Two grams proved to be as effective as either 4 or 8 grams.

Creep-feeding not so necessary when sows are self-fed. According to studies made by Terrill and associates of the Illinois Station [29] there is little if any advantage in creep-feeding the pigs when the sows are self-fed a well-balanced ration, and when ample feeder spaces are provided for the pigs, and when the number of sows and litters together is limited to three or four to the lot. In a test involving 24 spring and 10 fall litters, with generally three litters to each lot and Balbo rye or brome-bluegrass forage available, they found no significant difference in favor of the pigs provided with the creep. Under these conditions, even with the extra-special creep ration offered, the pigs consumd so little of it that its effect on gains was negligible.

Feed requirements of nursing sows. The best ration to feed the sow which is nursing a litter of pigs is the one which is cheapest and most productive of a large milk flow. It is so important that a full flow of milk be produced, however, that the balance and completeness of the ration should not be sacrificed for economy. The amount and quality of the milk supplied by the sow determines the rate of gain of the pigs, especially during the first four weeks. A ration of straight corn or other cereal is obviously inadequate. Even when balanced with protein supplements and minerals, it is still lacking. To meet all nutritional requirements, it is now known that to these there must be added feeds rich in vitamins.

It is important to note at this time the all-important fact that good lactation and pig survival are markedly influenced by the ration fed the sow during gestation. This principle was demonstrated in the

[28] Lawrence E. Carpenter, Pub. No. 61, 1951.
[29] S. W. Terrill, J. L. Krider, and G. W. Sherritt, A. S. 93b, April, 1949.

experiments reviewed in Chapter III. Inadequate rations during gestation mean lactation failure during the nursing period, and the best of feeding during lactation cannot overcome wholly the carry-over effect of a defective diet during gestation.

That the ration fed during the period of lactation does, however, affect the milk flow and the gains made by the pigs, regardless of previous treatment, is indicated by the results of a study of the protein requirements of nursing sows by Work and associates of the University of Hawaii.[30] Their test rations were made up of corn meal, standard middlings, crushed oats, soybean meal, fish meal, and a legume hay. One ration contained 14 percent of protein, the other 10 percent. Each was fed to 10 nursing sows in alternate periods. Pigs from the sows when on the higher-protein ration weighed 34.6 pounds at weaning time, while pigs from the same sows when fed the low-protein ration weighed 23.1 pounds. Weekly studies of the milk production of two sows showed the highest production during the fourth week of lactation, averaging 7.9 pounds daily on the high-protein ration, and 6.7 pounds on the low-protein ration.

Components of a good milk-producing ration. The essential components of a good milk-producing ration are (1) one or more of the cereal grains, as a cheap supply of carbohydrates; (2) a protein supplement, preferably partly of animal origin, sufficient to supply about 15 percent of crude protein in the ration; (3) a simple mineral mixture, especially when no animal supplement is fed; and (4) fine-quality alfalfa or other legume hay in an amount to represent about 10 percent of the ration by weight, or fresh green forage, mainly for their supply of vitamins and regulating effects.

Normally, the nursing sow requires a somewhat larger proportion of protein and mineral matter in her ration than is needed during gestation. The requirements are sufficiently similar, however, that good results may be expected by continuing the ration fed during the latter half of the gestation period, with but slight modification, during the lactation period.

Examples of good lactation rations. The following combinations of feeds are believed to contain all the nutrients in balanced proportions that are required to stimulate a maximum milk flow. The percentages are by weight, not measure.

[30] L. Work, A. Henke, and L. E. Harris, *Jr. An. Sci., Abs.*, Vol. I, No. 1, 1942.

Ration 1

Ground corn	60%
Ground oats	30%
Tankage or meat scraps	10%
Legume forage	

Ration 2

Ground corn	70%
Wheat shorts or middlings	20%
Meat scraps	5%
Soybean oil meal	5%
Legume forage	

Ration 3

Ground corn	20%
Ground oats or barley	14%
Skim milk or buttermilk	66%
Legume forage	
Simple mineral mixture	

Ration 4

Ground corn	30%
Ground oats	30%
Wheat middlings	20%
Fish meal	5%
Cottonseed meal	5%
Alfalfa meal	10%

Ration 5

Ground corn	50%
Ground oats	30%
35% protein supplement	10%
Alfalfa meal	10%
Simple mineral mixture	

Ration 6

Ground barley.	40%
Ground oats	30%
Wheat shorts	20%
Linseed or cottonseed meal	5%
Meat scraps	5%
Green forage	

Ration 7

Ground corn	53%
Ground oats	20%
Wheat middlings	15%
Forty-percent mixed protein supplement	12%
Green forage	

Ration 8

Ground oats	40%
Ground barley	30%
Wheat shorts	10%
Tankage, meat scraps, or fish meal	10%
Alfalfa meal	10%

The above rations contain from 14 to 16 percent of protein, not including that eaten in the forage. Where a simple mineral mixture was not recommended, the calcium content of the rations varied from 0.42 to 0.67 percent, and the phosphorus from 0.58 to 0.99 percent.

It will be noted that the above rations conform in their make-up to the following general plan or formula: Cereal grains + an animal protein supplement (or a combination of an animal and vegetable protein supplement, or a vegetable protein supplement and a mineral mixture) + green forage (or fine-quality legume hay).

A very satisfactory mineral mixture is equal parts by measure of wood ashes, steamed bone meal, limestone dust, and common salt; or two parts of limestone dust, two parts steamed bone meal, and one of common salt. Best results will be secured if the grain is ground, particularly the small grains. Whether the rations are fed in a slop or dry

is not a matter of much concern, although the more common practice is to slop.

Amount to feed. The results, in hand-feeding, will depend very much on the care and judgment of the feeder in determining the amount which should be fed. Sows which have six or more pigs to nurse should be fed full rations. Even when given all the feed she will eat, the average sow in moderate condition at farrowing time will lose between 25 and 65 pounds during the lactation period. The fatter the sow at farrowing time, the greater will be the loss in weight. One hundred sixty-five sows at the Indiana Experiment Station that had been experimentally fed full rations during the winter and which were heavy fat at farrowing time lost an average of 81½ pounds during the subsequent nursing period. This did not include the loss of weight which occurred in farrowing. Self-fed sows lose less than those which are hand-fed. Studies have shown also that the heaviest milking sows are usually the biggest eaters and the heaviest losers. In hand-feeding, therefore, the amount fed at any feed should be regulated by the appetite, just a little less being given than would be taken. This method will ensure the maximum feed consumption and result in cleaner troughs. A good sow will eat from 10 to 14 pounds of dry feed daily, or about 3 pounds daily per hundredweight. Deep-milking sows with large litters may with advantage be fed three times a day.

If the sows can be fed individually at this time, it will not only be an aid to good feeding but will result in greater uniformity of the pig crop. Two or three sows with pigs approximately of the same age, however, may occupy the same lot and be fed together with good results. The practice of allowing all the sows with pigs of all ages and sizes to run together is the surest way to encourage "robbing" and the production of a large proportion of runts. If it is necessary that several sows occupy the same quarters, those only with pigs of about the same age should be placed together.

In every herd there are commonly a few sows to be found which are nursing but two or three pigs each. Such sows usually employ their food for the production of fat rather than milk, and when their pigs are four or five weeks of age, they start taking on weight. In case the small litters are the result of accident and not of any deficiencies of the sows themselves, they should be fed the amounts which will maintain them in fair flesh. On the other hand, if the small litters are the result of natural inferiority or neglect on the part of the sows, full

rations should be continued and the sows sent to market as soon as their pigs are weaned, or soon afterward.

Self-feeding nursing sows practical. Although hand-feeding is still preferred by the breeder, an increasing number of commercial producers is adopting the self-feeding plan, especially when large numbers are involved. It saves labor, and when the number of sows and litters lotted together does not exceed three or four, and when sufficient feeder space is provided, the results are practically as good as those obtained in hand-feeding. When all the sows with litters of different ages are run together, however, and when creep-feeding is not practiced, the results as measured by the size and quality of the pig crop at weaning time are disappointing.

Water supply important. The average sow when nursing a litter of pigs requires four to five gallons of water daily as drink. Regardless of the ration fed, a large milk flow is impossible without generous water consumption. Garner and Sanders [31] found that 37 Large White sows consumed during the nursing period an average of 42.7 pounds of water daily. These sows drank as much water in winter as in summer, and there appeared to be no relation between the number of pigs in the litter and the water consumption. The consumption tended to decline with the advance of lactation. These facts emphasize the need for attention to this important item of management.

Raising orphan pigs. On most hog farms the pigs which may be left without a mother can be distributed among the other sows whose litters are of about the same age. Occasionally, however, conditions are such that this transfer is not possible and the time and detailed attention required to raise them by hand is justified.

Cow's milk containing from 3 to 3½ percent of fat probably is the most suitable food for the orphan pig. Even after he has begun to eat dry food, it should constitute the principal part of his diet. Although sow's milk is considerably richer both in protein and fat than cow's milk, Beach [32] found that digestive troubles were less likely on thin than on rich cow's milk. Evvard's studies [33] showed that there was little if any practical advantage in modifying cow's milk by adding to it casein, blood meal, or linseed-oil meal sufficient to increase the protein content 1 percent, or to the level of sow's milk.

[31] F. H. Garner and H. G. Sanders, *Jr. Agr. Sci.*, Vol 27, No 4, 1937.
[32] C. L. Beach, Conn. Exp. Sta., Bul. 31, 1904.
[33] John M. Evvard, Ia. Exp. Sta., Res. Bul. 79, 1923

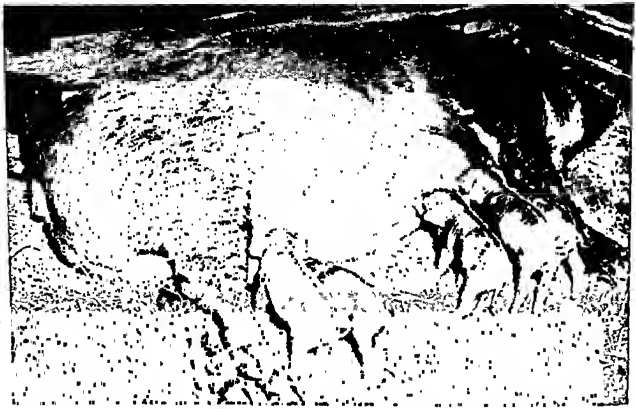

Fig. 22. Three inverted nipples, or "blind" teats, on the right side. The number of pigs raised is limited to the number of functional teats available *(courtesy, Prof. L. A. Weaver and Mo. Exp. Sta., Bul. 461, 1943).*

If the pig has had a few nursings of the first milk of its mother or some other sow, it will be greatly to his advantage. For the first few days the milk should be fed at body temperature, especially when the weather is cold. Frequent feedings are also desirable. It is well to remember that the very young pig normally nurses every 1 to 2 hours. A good rule is to feed at first every 2 or 3 hours during the day, beginning at five o'clock in the morning. The second week the number of feedings for the 24-hour period may be reduced to five or six, and the third week to four or five. When the pig starts eating dry feed, the schedule may be appropriately reduced to three or four feedings a day.

By immersing his nose in the milk a few times, the pig will soon learn to drink from a shallow pan. It is better to use a shallow pan than the ordinary trough because it will be easier to clean, and cleanliness is imperative. The use of the bottle and rubber nipple is not practical. The amount fed should be governed by the capacity of the individual pig to take it without causing scours. Some will take more than they can digest. For the first month the pig will consume about 1 quart daily, on the average. It is doubtful if he should ever be fed more than 1½ quarts daily at any later time.

Green and associates of the Minnesota Station [34] in a valuable study, "The Artificial Rearing of Baby Pigs," report excellent results by employing a self-feeding method. Baby pigs ranging in age from those that had not nursed up to those 1 week of age at the start of the tests were used. A fresh supply of 3½ percent pasteurized cow's milk was provided each morning in thoroughly sterilized 5-gallon galvanized iron cans so equipped that when inverted over the trough 1 inch of milk was kept in the trough at all times. Air bubbles rising in the can when the pigs drank provided sufficient agitation in the milk to prevent "creaming out." No trouble was reported from scours which might be attributed to ad libitum feeding. The pigs thrived; eight of them weighed from 45 to 60 pounds at eight weeks of age.

These investigators demonstrated that baby pigs will do well when self-fed on pasteurized cow's milk, and they described the equipment and the methods of sanitation and sterilization which it is necessary to employ in order to prevent contamination of the food supply. The chief problem, and the one most difficult to solve in practice, would seem to be represented by the difficulty of maintaining all milk utensils in a thoroughly aseptic condition at all times.

Weybrew and associates of the North Carolina Station [35] successfully raised baby pigs in screen-floored cages from 2 days of age past the sixth week on three reconstructed milk diets, as follows: (*A*) evaporated milk, (*B*) reconstructed skim-milk solids plus butter, and (*C*) reconstructed whole-milk solids. Each diet has added to it appropriate mineral supplements and cod liver oil. The pigs were pan fed four times daily at 4-hour intervals in amounts that would be taken in 30 minutes.

At the normal weaning age of 8 weeks the average weight of the pigs was as follows: on Diet *A*, 35 pounds; on Diet *B*, 46.8 pounds, and on Diet *C*, 48.6 pounds. The average weight of the pigs in a comparable group of three litters which suckled their dams on pasture with access to a self-feeder was 33.9 pounds.

Orphan pigs should be given every advantage in the way of clean drinking vessels, sanitary quarters, green feed, exercise, and sunshine, if they are to do well. They should be encouraged to take dry feed at an early date. Measures for the prevention of anemia should not be neglected.

[34] W. W. Green, H. H. Brugman, and L. M. Winters, *Jr. An Sci.*, Vol 6, No. 2, 1947.

[35] J. A. Weybrew, H. A. Stewart, G. Matrone, and W. J. Peterson, *Jr. An Sci.*, Vol. 8, No. 2, 1949.

Castration. Tests made by Warwick and VanLone [30] of the Wisconsin Station indicate that pigs castrated the first week of their lives, or at birth even, show as low mortality and as strong growth vigor later as the females in the same litter, or those castrated when between the ages of 4 and 5 weeks. Under farm conditions, probably the earlier the pigs intended for market are castrated the better the results will be. Compared with the method of castration just before or after weaning, it has several advantages. The wounds heal more quickly, the pigs are easier to handle, they are under closer supervision, and they seem less likely to become infected.

Although this is not a dangerous nor a complicated operation, certain precautions will help to reduce the likelihood of complications. So far as possible the pigs should be empty of much feed; one should avoid getting them warmed up and excited when penning them; a whetstone should be handy and the knife kept sharp. A pan of strong disinfectant, such as a 4-percent solution of a coal-tar dip, should be at hand in which the knife is placed between operations and which should be used to sponge off the scrotum before operating. In performing the operation it is important that the incision be made low enough to prevent any accumulations of the drainage into the base of the pouch. With young pigs the cord should be pulled out or broken off well forward. It is important that the hands of the operator and the knife be kept clean. After the operation the best place for the pigs is a clean pasture; the worst is a germ-infected, dusty dry lot containing convenient wallows (see Chap. XXII).

Vaccination. There can no longer be any question concerning the wisdom of permanently immunizing pigs against cholera, especially in the more densely populated swine areas. Where vaccination is not regularly practiced, a visitation of the disease may be depended on every 3 to 5 years, and it is so devastating in its effects that protection purchased at a cost of around a dollar a head is cheap insurance. On those farms which produce pedigreed hogs, the risk is still greater. The probability of infection is increased by the purchase and exchange of breeding stock, by visitors and prospective buyers, and by showing at the fairs. Another important fact is that the sanitary restrictions of most states now require a cholera vaccination certificate before a hog may be brought into the state.

The older the pigs are when vaccinated, the more important is it

[30] B. L. Warwick and E. E. VanLone, Reprint, *J. Vet. Med. Ass'n*, Vol. LXIX, N.S. 22, No. 5, Aug., 1926.

to restrict their feed. Especially with pigs weighing 40 or 50 pounds, the morning feed should be omitted or the feeder closed the night before. They will withstand the excitement of driving, catching, and holding much better when empty than when full of feed. Full rations should not be given for 2 or 3 days after. Many believe that complications will be very much less likely to occur under these conditions.

Although week-old pigs have been permanently immunized against cholera by the usual serum-virus treatment, most veterinary authorities have concluded that life-time immunity is best ensured by vaccinating when 6 to 8 weeks of age. Regardless of age, however, successful results are possible only when potent serum and virus are used on healthy pigs (see Chap. XXII).

Weaning the pigs. The pigs usually should be weaned when 8 to 10 weeks of age. If they have had up to this time the advantage of a creep and good rations, they will scarcely miss the mother's milk, which is secreted in rather limited amounts at this time. Those sows which are to raise fall litters should be taken from their pigs at 8 weeks, since sows usually do not come in heat while suckling their pigs, and early fall litters are desirable. On the other hand, sows which are extremely heavy milkers and which are not to be bred may with profit be allowed to nurse their pigs for 12 weeks, provided they are liberally fed. A few days before the sows are removed from their pigs their rations should be materially reduced. This precaution will tend greatly to eliminate the conditions which favor inflamed and caked udders at weaning time. It is commonly more convenient to remove the sows than the pigs. Some recommend that the sows be put back the next day and the pigs allowed to nurse partially. This may be desirable with individual sows, but as a rule it should be unnecessary. When separated, the sows should be put into a dry lot and fed only scanty rations for a few days until their udders begin to shrivel and dry up.

Gains of pigs from birth to weaning. The average pig in a well-managed herd should make an average daily gain of ½ pound from birth to weaning time. This would mean a weight of approximately 30 pounds when weaned at the age of 8 weeks. Under the best of conditions, however, there is a wide variation among the individual pigs, ranging from a daily gain of less than ⅓ to over ¾ pound.

In Table 21 are shown the average weekly gains, and the average daily gains by weeks, of 22 litters of 166 pigs during the first 7 weeks of the nursing period. These summarized data are from detailed

records of 12 litters at the Wisconsin Station[37] and 10 litters of the Purdue University herd. Both sows and litters were liberally fed on good growing and milk-producing rations during the suckling period.

Table 21. Showing Weekly Gains of Pigs from Birth to Seven Weeks of Age

	First Week	*Second Week*	*Third Week*	*Fourth Week*
	lb.	lb.	lb.	lb.
Weekly gains per pig	2.63	3.08	2.79	3.15
Daily gains per pig	0.38	0.44	0.39	0.45
	Fifth Week	*Sixth Week*	*Seventh Week*	*Total Seven Weeks*
Weekly gains per pig	3.19	3.35	4.39	3.22
Daily gains per pig	0.46	0.48	0.63	0.46

These figures are conservative and show the remarkable capacity of the new-born pig for growth. During each of the 7 weeks these pigs gained an amount considerably in excess of their birth weight. The original weight was doubled the first week. The weight at the end of the 7-week period was more than eight times the birth weight.

A study of the individual litters here summarized revealed the interesting fact that the pigs in the small litters did not gain any faster than did the individual pigs in the large litters (see Chap. V). Another observation, which may be made from the table, is that the gaining capacity increases regularly from week to week, except for a break which occurs during the third period. This latter undoubtedly is the result of the fact that it is about three weeks after birth that the pigs are likely to become more or less anemic, a condition from which recovery immediately follows under good feeding conditions (see page 91).

Some Production-Registry records. To show how far short good average performance actually falls below possible accomplishment, there are given here the officially attested records of the top six sows of each of seven breeds which are participating in the all-breed Production-Registry program as organized and sponsored by the National Association of Swine Records. The average weaning weight of these 42 litters at 56 days of age was 543 pounds. The average number of pigs per litter of six of the breeds (records for one breed were not

[37] W. J. Carlyle, Bul. 104, 1903.

available) was 11.69, which had an average weight at weaning time of 46.9 pounds. Assuming a birth weight of 3 pounds, this represents an average daily gain during the nursing period of 0.78 pound.

The record of one of these sows, Miss Fancy 51082, is especially noteworthy. Her first litter was farrowed September 20, 1945, and her ninth litter September 10, 1949. Each was a Production-Registry litter. She farrowed an average of 11.9 pigs to the litter and raised an average of 10.3. At weaning time the litters averaged 522 pounds.

CULLING OUT THE UNPRODUCTIVE SOWS

The best time of year to make an accounting with the sows is after they have weaned their pigs. They have individually just finished a test of performance which offers the best and most practical basis for the selection of future breeding stock. As a general rule, only those sows which have produced good-sized even litters of pigs and suckled them well should be retained for another breeding season. The prolific, heavy-milking sow, though "thin as a rail" when her pigs are taken from her, is the foundation of every successful herd of hogs. Such a sow should hold her place in the breeding herd so long as there are no better ones, according to the same standard, to take her place. Mature sows which fail to raise litters of seven good pigs under good management conditions should ordinarily be put into the fattening pen. Although they may be smooth and good to look at, the herd from a pork-producing standpoint should be rid of them. Sows with defective teats, the sows with mean dispositions, the gilts which did not perform up to expectations, the pig killers, and the poor milkers should be disposed of. No market-producing herd can be brought up to and maintained at a high level of breeding performance without constant culling, and no herd of pedigreed stock can be made to succeed where "looks" and not performance is the test in selection.

Fattening the cull sows. Those sows which are to be discarded should ordinarily be given a short period of intensive feeding in confined quarters, sufficient to put them in moderate condition before being sent to market. Normally, the effort should be made to get them to the "yards" early in order to avoid the glut of "packer" hogs, which normally occurs during the late summer. So long as the lard market continues in its present state of collapse, feeding them longer than a few weeks is not advisable.

Should fattening sows be bred? The common farm practice of turning the boar in with the sows that are being fattened for market was

investigated by Johnson and Wright of the South Dakota Station.[38] In a survey of the hogs marketed in August, 1945, at the Morrell Packing Plant of Sioux Falls, South Dakota, they found that the "kill" consisted of 29.7 percent barrows, 35.3 percent open sows, and 35 percent of sows which had been bred. In this latter group of "piggy" sows, one-third had carried their foetal litters less than 60 days, and one-third more than 80 days.

Feeding and slaughter tests comparing bred and open sows were made in three successive years, 1943 to 1945. Following the weaning of their pigs, in June and early July, the sows were divided into two similar lots and fed well-balanced rations on rape pasture for an average period of 57.5 days. The sows in one lot were bred as they came in heat; those in the other lot remained open. Eighty-five percent of the sows bred became pregnant.

The bred sows consumed more feed and gained faster than the open sows. After deducting the extra weight due to the foetal litter from the final weight, the bred sows outgained the open sows by the difference of 2.00 and 1.91 pounds daily; the feed required to produce a hundred pounds of gain, on the same basis of calculation, was 494 and 503 pounds, respectively; the dressing percentage in the two groups was practically identical, 80.3 and 80.4 percent, respectively. There were no important differences observed in the quality of the carcasses. But the 17 "piggy" sows sold for $13.06 per hundredweight, and the 23 open sows sold for $13.42.

Chiefly because of the difference in selling price, the authors concluded that the practice of breeding sows during the fattening period was undesirable and unprofitable from the standpoint either of the breeder or packer.

Spaying sows not practical. J. F. Braga[39] compared 10 spayed with 10 entire sows during a 120-day fattening period. He found that, although the spayed sows gained faster on less feed, the difference was so slight that the extra cost and risk involved in the operation were not justified.

HERD RECORDS

In the management of a pedigreed herd, a systematic and detailed set of permanent records is imperative. The reliability of every pedigree rests not only on the integrity of the breeder, but also on the faith-

[38] Leslie E. Johnson and Turner Wright, *Jr. An. Sci.*, Vol. 7, No. 1, Feb., 1948.
[39] Abs. 172, *Animal Breeding Abstract*, 16 (1), 41.

fulness and care with which the records have been kept. It is desirable, therefore, that the system of record keeping adopted possess the following features: it should provide for the statement of all essential facts, *i.e.*, it should be complete; it should be logically and systematically arranged; it should be as simple as possible and adapted to the needs of the individual breeder; and it should be of a kind which will ensure permanency.

The records may be kept either in specially made book form or on suitably ruled cards which may be indexed. Each form has its advantages. The publishers of practically all breed papers now put out private herd record books which are furnished to the breeders at a nominal cost. These have done much to encourage the systematic keeping of records and to give confidence in the results of pedigree registrations generally. These books are inexpensive, convenient to use, and entirely satisfactory. They are especially recommended for breeders who are poor bookkeepers.

In addition to the sow and litter divisions, a complete record system should also provide spaces for (a) an extended pedigree of each boar and a list of the sows to which he has been bred during the year; (b) a summarized record of the individual animals bought and sold; and (c) an index. If such a system is supplemented by giving each sow in the herd which has produced two or more litters a page or card upon which may be recorded a summarized statement of the litters she has produced, the number of pigs farrowed and raised in each, the number retained, and the number sold and total value, it will facilitate the study of the performance records and ensure a more accurate estimate of the value of each sow in the herd.

V Size of Litters; Birth Weight of Pigs; Milk Flow of Sows

In the following pages some figures are given which show the influence of certain factors on the size of litters, birth weight of pigs, and the milk flow of sows. Since the usefulness and value of a sow are largely determined by her performance in these particulars, the studies should be of interest.

SIZE OF LITTERS

The ability of the sow regularly to produce large litters is the most fundamental and valuable of those traits which determine her usefulness in the breeding herd. In view of this, it is of considerable importance to learn what factors are responsible for its wide variation and the extent to which these are under the control of the breeder or feeder. The following factors will be considered in their possible relationship to the number of live pigs farrowed: age of the sow, feeding and condition of the sow when bred, crossbreeding, inbreeding, the boar with which the sow is mated, prenatal deaths, type and breed.

Age of sow. The number of pigs per litter farrowed varies widely among the sows of the same and different herds. That some of this variation is due to differences in the ages of the sows is commonly believed. In Table 22 are presented data assembled by Rommel[1] from a study of the farrowing records of 6145 sows recorded in Volume 36 of the American Poland China Record.

In Table 23 are presented the results of a similar study by Lush of the Iowa Station and Molin of the U.S. Department of Agriculture.[2] These data, which include records on 7415 litters for number of live pigs farrowed, and 4920 litters for number weaned, were derived from records reported for eight State college and experiment station

[1] Geo. M. Rommel, U.S.D.A., Bu. An. Ind., Cir. 112.
[2] Jay L. Lush and A. E. Molin, U.S.D.A., Tech. Bul. 836, 1942.

Table 22. Size of Litters of Sows of Different Ages

Age of Sows	*Number of Litters*	*Average Number of Pigs per Litter*
1 year	2010	6.64
2 years	2047	7.56
3 "	1157	7.88
4 "	606	8.26
5 "	325	8.40

herds, and for the experimental herd maintained by the U.S. Bureau of Animal Industry. The data considered here include only the records of sows up to and including those six years of age.

Table 23. Size of Litters Farrowed and Weaned by Sows of Different Ages

	Number of Live Pigs Farrowed		*Number of Pigs Weaned*	
Age of Sows	*Number of Litters*	*Average per Litter*	*Number of Litters*	*Average per Litter*
(years)				
1	1838	7.92	1223	5.07
1½	1181	8.49	759	5.53
2	1515	9.49	978	5.99
2½	937	9.49	643	5.67
3	772	9.88	532	5.47
3½	448	9.93	307	5.68
4	339	9.58	230	5.07
4½	162	9.76	114	5.18
5	112	9.42	76	4.86
5½	48	9.04	32	5.78
6	34	8.82	21	4.76

The results indicate that the 1½- and 2-year-old sows farrow and raise larger litters than those 1 year of age, and that 2½- and 3-year-old sows farrow larger litters than 2-year-olds. Records for the sows reported by Rommel show an increase in number farrowed up to and including those 5 years of age. Lush and Molin's data indicate an increase in number up to and including only those in the 3½-year group. With some exceptions, the number per litter weaned varied directly with the number farrowed. These averages are based on a sufficient number of observations to make them indicative of the fertility of sows of different ages as they are found in the general population.

These results should not be interpreted to mean that the individual

sows, 176 produced their fourth litters, the average for which was 0.22 pig larger than their third litters. In the same way, it is determined that the fifth litters were 0.239 pig smaller than the fourth, while the sixth slightly exceeded the fifth litters. The seventh litters were very much smaller than the sixth, while of the 18 sows producing eight litters, the eighth slightly exceeded the seventh. Only 7 of these sows produced their ninth litters, and only 5 their tenth, but with these litters there was a decided decrease in their size.

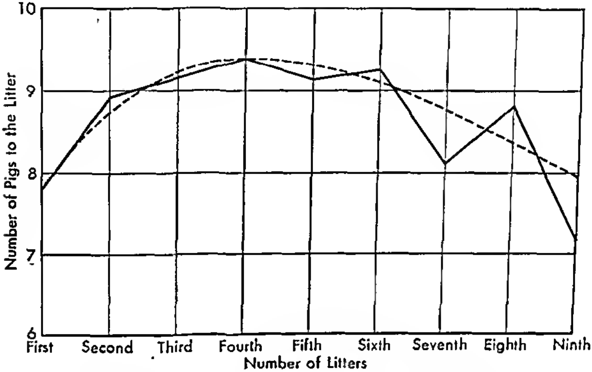

Fig. 23. Variation in the number of pigs in successive litters.

These results, expressed graphically in Fig. 23 will show more clearly the fluctuations which may be expected in the size of the successive litters of any individual sow.

According to this curve, a sow may be expected to produce an increasing number of pigs up to and including her fourth litter. From the fourth litter on, she may be expected to produce a decreasing number with each succeeding litter. The number of sows with records here of seven, eight, nine, or ten litters is too small, however, for the averages to have significance. The extreme fluctuations shown in the latter part of the curve would be made to disappear if a larger number of records for these ages was available. As a result of this limitation of numbers, the broken line is a more reliable indication of the performance.

No attempt was made in this study to allow for the sow producing two litters a year. It is believed, however, that she will as closely approximate the curve shown as she would if producing but one. The large increase of the second over the first litter was probably the result of the fact that many of the sows produced their second litter after a rest of six months. The average size of the litters here reported was slightly over nine.

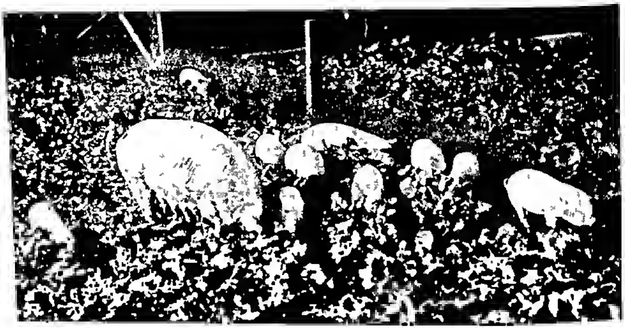

Fig. 24. When this young sow was less than 1 year old she farrowed 12 pigs, the 11 surviving averaging 45 pounds when 58 days old. Note her "suckled-down" condition. Just before farrowing she weighed 450 pounds; when this picture was taken she weighed 330 pounds. She lost 80 pounds in weight during the nursing period despite the liberal feeding of a rich milk-producing ration.

Feeding and condition of sow. It has been observed by hogmen that the way a sow is fed the week or two before breeding has some influence on the number of eggs secreted when she comes in heat and on the size of the resulting litter. It is not so much the direct effect of feeding alone, although this tends to stimulate the ovaries, as it is the state of health and thrift brought about by a combination of judicious feeding and liberal exercise during the months preceding (see page 25).

That low fertility, or even complete sterility, may result from excessive fatness is also a fact clearly established by experience. Sows which have been highly fitted for show, especially if maintained in this extreme condition for a considerable time, require skillful handling before regular breeding habits can be restored. Excessive quantities of fat about the generative organs would seem to offer a me-

chanical obstacle to the normal nutrition of the egg-secreting ovaries, and to the free passage of the eggs after secretion down the Fallopian tubes to the uterus. When to excessive fatness there is added the evil of close confinement, the breeding qualities are very likely to suffer permanent injury.

Crossbreeding. Although crossbred pigs, as a rule, are slightly more vigorous at birth, the number of stillborn is less, and the percentage of those farrowed surviving to weaning time is greater, the number of pigs farrowed is not significantly affected.

This is the general conclusion reached by Lush and associates of the Iowa Station [4] after a comprehensive survey of the crossbreeding work in the United States and foreign countries together with their own experiments from 1926 to 1933.

Carroll and Roberts of the Illinois Station [5] made a similar survey and analysis of data from 12 experiments involving the production of 2619 purebred and 1515 crossbred litters. Only those experiments were considered in which it was possible to compare the crossbreds with purebreds produced by both the parental breeds, since only under these conditions was it considered possible to obtain a reliable estimate of the value of crossbreeding. Based on the average results secured from the individual experiments, the average size of the purebred litters from the better of the two parental groups was 10.1 pigs, for the purebreds produced by the parental group of lesser prolificacy it was 9.4 pigs, and for the crossbred litters it was 9.5 pigs, intermediate between the litter size of the two parental purebreds.

The Iowa studies included a comparison of litters produced by 18 crossbred and 20 purebred sows. The crossbred sows when mated with boars of one of the parent's breed, or with a boar of a third breed, produced 10.6 pigs to the litter, while the purebred sows mated to boars of their own breed farrowed an average of 9.2 pigs. The average number of pigs weaned was 10 and 6.85, respectively, which represented 85 and 74 percent of those farrowed.

Inbreeding. Although its effect varies, continuous inbreeding results in a decline of litter size, even though in practice only the more prolific gilts are selected for mothers of the next generation. This conclusion is supported by the evidence of numerous and extended studies of inbreeding that have been made during the past 30 years. From an analysis of the records of the Minnesota swine breeding project,

[4] J. L. Lush, P. S. Shearer, and C. C. Culbertson. Bul. 380, 1939.
[5] W. E. Carroll and E. Roberts. Bul. 489, 1942.

Stewart of the University of Minnesota [6] found that an increase of 10 percent in the inbreeding of the dams of the same age resulted in a decrease of about 0.6 pig per litter. His data also showed that the inbreeding of the litter has little or no adverse effect on litter size when the age and inbreeding of the dams are the same.

In a similar study of data from the inbreeding experiments conducted at the U.S. Department of Agriculture experimental farm at Beltsville, Md., Hetzer and associates of the Bureau of Animal Industry [7] concluded that "differences in the inbreeding of the litter appeared to have had a greater effect on litter size at the various ages than did differences in the inbreeding of their sires or dams." Analysis of the data also showed that not more than 20 percent of the variations in litter size is hereditary. There is considerable practical significance attached to this point, for it is a measure of the effectiveness of selection in improving herd fertility. This does not mean, of course, that fertility is less than 20 percent hereditary.

Influence of the boar. The number of pigs produced by the sow in a given litter cannot exceed the number of eggs which mature during the heat period in which she is bred. Since the fertile boar supplies in a normal discharge more than a million germ cells, or sperms, for each egg produced by the sow, it would appear, when both parents are fertile, that the sow is chiefly responsible for the number of pigs farrowed.

That the boar may be and perhaps often is responsible for small litters, however, is the belief of experienced hogmen. That this sometimes is the case is proved by the results of a study made by Nordby of the Idaho Station [8] of the boar Discount. A group of 10 highly selected purebred sows had produced in the spring of 1927 and the following autumn to the service of normal fertile boars a total of 180 pigs for the two seasons, or an average of 9 pigs to the litter. The boar Discount was then introduced into the herd. To the service of this boar the same 10 sows farrowed in the spring of 1928 a total of 34 pigs, or an average of 3.4 to the litter. In the two previous seasons the litters ranged from 7 to 10. Those sired by Discount varied from 1 to 6. In no case did a sow farrow as large a litter by Discount as she did in either of her two litters by the boars previously used.

When submitted to laboratory examination the semen of Discount

[6] H. A. Stewart, *Jr. Agr. Sci.*, Vol. IV, No. 3, 1945.
[7] H. O. Hetzer, W. V. Lambert, and J. H. Zeller, U.S.D.A. Cir. 570, 1940.
[8] J. E. Nordby, *Jr. Am. Vet. Med. Assn.*, Vol. 74, N.S. 27, No. 6, 1929.

in comparison with the semen from the other boars was found to be almost impotent. Microscopic study revealed that his spermatozoa rated only 8 percent in motility, whereas the samples from the other boars rated from 95 to 99 percent in activity. On the first examination of the fresh semen of Discount there was found but 8 percent of living spermatozoa. In contrast with this, the vitality of the spermatozoa from the other boars was 98 percent perfect.

The author submitted the interesting observation that Discount was vigorous in appearance, was well developed, and that the manner in which he served was such as to give rise to no suspicion with respect to his fertility. That sterile or partially fertile boars frequently are prompt and active in service is the conclusion also of Anderson of the Kentucky Station [9] who made laboratory studies of two similar cases.

Microscopic studies of the semen of boars by McKenzie and Johnson of the Missouri Station [10] indicated that the number of abnormal spermatozoa was correlated with the degree of fertility. Boars whose semen contained only 62 to 104 abnormalities per 1000 consistently sired large litters of strong vitality, whereas those whose semen contained as many as 146 to 501 per 1000 generally sired small litters containing mummies or weak pigs. The abnormalities found were small heads, tapering heads, and enlarged middle pieces. That the excessive use of boars results in the production of a greatly increased proportion of defective and abnormal sperms, as well as a reduced number of normal sperms, was shown in later studies at the same station.

Prenatal deaths. Death losses which occur during the prenatal period of development are surprisingly high in pigs. The extent of these losses has been shown by the studies of a number of scientists, including Corner,[11] Crew,[12] Hammond,[13] Parkes,[14] and Warwick.[15] Instead of secreting 8 to 12 eggs at each ovulation or heat period as is generally supposed, the fertile sow normally produces 18 to 20, and even more These investigations clearly showed that of this total number of fertilized eggs, only two-thirds on the average survived to farrowing time. This loss in utero does not occur at any one critical time, but

[9] W. S. Anderson, Res. Bul. 244.
[10] C. C. McKenzie and S. R. Johnson, Bul. 328, 1933.
[11] C. G. Corner, Am. Jr. Anat., Vols. 31-32, 1923.
[12] F. A. E. Crew, Proc. Royal Soc. of Edin., Vol. 46, 1926.
[13] John Hammond, Jr. Agr. Sci., Vol. 11, 1921.
[14] A. S. Parkes, Jr. Agr. Sci., Vol. 18, 1928.
[15] B. L. Warwick, Jr. Morph. and Phys., Vol. 46, No. 1, 1928.

seems to be fairly well distributed throughout the gestation period. Corner concluded that approximately 10 percent of the eggs, although fertilized, do not segment; a second 10 percent degenerate before implantation, which occurs two weeks after ovulation; and that a further 5 to 10 percent die during implantation and subsequent pregnancy.

The following factors or conditions which affect the life of the pigs in utero may be regarded as probable causes for this high mortality: (1) overcrowding, the result of a large number of pigs and a consequently limited uterine surface area available for the nourishment of the individual embryos; (2) nutritionally incomplete rations fed the mother during the gestation period, especially those deficient in protein, calcium, or vitamins A or E; (3) a lack of natural vigor or development in the uterus of the sow; (4) the presence in the fertilized egg of hereditary lethal, or death-dealing, factors which prevent normal development; or the presence in the egg of an insufficient number of the hereditary factors for vigor, as commonly results from inbreeding; (5) partial sterility on the part of the boar as the result of weak or partially potent sperms; (6) excessive fatness on the part of the sow, or illness; (7) disease; and (8) accidents or injuries.

Breed and type. Although it cannot be claimed that all breeds are equal in their ability to farrow large litters of pigs, it is equally true that there is insufficient evidence to support the claim that one breed is superior to another of the same type. So many factors, both hereditary and environmental, affect pig-producing ability that it is doubtful if superiority for any breed can ever be established. That some breeds are more prolific than others, on the average, however, probably is true. If this is so, it is because their breeders have been more persistent in selecting for this character, and less influenced by fancy points and show-yard records.

Breeders generally hold to the view that long-bodied sows as a rule are more prolific than short-bodied sows. This view, which is based on observation of farrowing results, seems a reasonable one. Experimental tests that have been made to determine the relation between the type of sow and the number of live pigs farrowed per litter generally support this claim.

Evvard and Culbertson of the Iowa Station [10] obtained farrowing records on 12 Big (rangy) type, 43 Medium (intermediate) type, and 9 Small (chuffy) type sows, from 1917 to 1923, inclusive. The classification was determined by size, length of leg, length of body,

[10] J. T. Evvard and C. C. Culbertson, *Study of Swine Types*, 1923.

size of bone, and general ruggedness. The average number of live pigs farrowed per litter for the Big type was 8.41, for the Medium type 8.30, and for the Small type 6.44. The number of sows in the test, particularly the number of those representing the two extremes of type, was too small to warrant a definite conclusion. The results suggest, however, that sows of the Small or chuffy type are not as prolific as those of the Medium or Big types.

Hetzer and Brier of the U.S. Department of Agriculture [17] made a similar study of 43 Large type, 51 Intermediate type, and 26 Small type sows, from 1931 to 1938. Differences in the results, which might have been due to differences in the age of the sows or the year, were eliminated by maintaining the same proportion of the types in each year. The number of pigs farrowed per litter was 7.4, 6.6, and 5.8, respectively. These differences were adjudged significant. It was concluded that most if not all of the differences in litter size resulting from type differences were genetic in character.

Number of pigs raised. The number of pigs farrowed is not so important as the number raised. Although the most prolific sows in the herd raise more pigs, as a rule, than do those which produce smaller litters, they do not raise so large a percentage of those farrowed. This seems to be especially true when mature sows are compared with gilts. In the following table are summarized the records made by mature sows and gilts at the North Platte, Nebraska, Experiment Station.[18] The test included 87 litters produced by gilts and 72 litters by mature sows in 1910, 1911, 1912, and 1913. The large number of individuals studied makes the results particularly valuable.

Table 25. Percentage of Pigs Raised by Mature Sows and Gilts

Number of Litters		*Total Number Pigs Farrowed*	*Number Pigs Farrowed per Litter*	*Number Pigs Raised per Litter*	*Percentage of Farrowed Pigs Raised*
Mature sows	72	791	10.9	6.56	60
Gilts	87	714	8.2	6.25	76

The data of Lush and Molin, included in Table 23, suggest that the number of pigs per litter raised to weaning time is at a maximum when sows are 2 to 3 years of age, and with a tendency to decline slightly as the age advances.

[17] H. O. Hetzer and G. W. Brier, *Proc. A. Soc. An. Prod.*, 1940.
[18] W. P. Snyder, Bul. 147, 1915.

As bearing on the same point, the number of pigs farrowed dead or immature in litters of different sizes is also instructive. The author is indebted to W. J. Carmichael of the Illinois Station [19] for these data which are presented in Table 26.

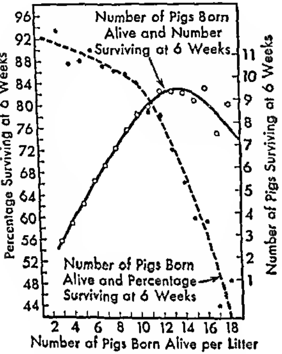

Fig. 25. Effect of litter size at birth on mortality up to 6 weeks (based on 1752 litters). Although the percentage of live pigs farrowed which survived at 6 weeks decreased as the size of the litters increased, the number of pigs which survived increased as the number farrowed increased up to 12 or 13 *(courtesy, Menzies-Kitchen,* J. Agr. Sci., *Vol.* 27, *p.* 611, 1937*)*.

Although a larger number of dead or immature pigs are farrowed in litters containing 10 or more pigs, it would appear that in litters smaller than 10 the number of pigs farrowed dead or immature is not greatly affected. When the proportion of dead or immature pigs is considered,

Table 26. Effect of Size of Litter on Number of Dead or Immature Pigs

Number Pigs per Litter	*Total Number of Litters*	*Dead or Immature Pigs per Litter*	*Percentage of Dead or Immature Pigs*
4	39	0.36	8.97
5	57	0.40	8.07
6	66	0.38	6.31
7	84	0.71	10.71
8	86	0.43	5.37
9	72	0.87	9.72
10	78	0.72	7.17
11	53	1.30	11.83
12	33	1.27	10.61
13	25	1.56	11.89
14	11	3.36	24.02
15	5	0.60	4.00
16	3	1.66	10.41

[19] *Master thesis*, University of Illinois, 1916.

the table does not show any greater loss in the larger litters, up to 10, than in the smaller ones. When the number of pigs to the litter exceeds 10, however, there is a regular tendency, both absolutely and relatively, for the number farrowed dead or immature to increase with the increased size of the litter.

A study made by Severson of 3779 pigs farrowed in 393 litters at the North Dakota Station,[20] from 1909 to 1924 inclusive, showed the relation between size of litter and the percentage of pigs raised to market age to be as indicated in Table 27.

Table 27. Relation of Size of Litter to the Number of Pigs Raised to Market Weight

Number Pigs per Litter	*4 to 6*	*7 to 9*	*10 to 12*	*13 to 17*
Percentage of pigs marketed	55	66	67	63

The author observed also that, contrary to the general belief, the individual pigs in the larger litters gained as rapidly as did those in the smaller litters.

Studies by Wenck of 3619 pigs produced on five farms in East Prussia [21] indicated that pigs farrowed in litters of seven were most likely to survive. His records showed that the farrowed pigs which survived at four weeks of age increased from 67 to 91 percent as the size of the litter farrowed increased from three to seven; but as the litter size increased beyond seven there was a regular decrease in the percentage of farrowed pigs surviving. The actual number of pigs raised to the litter, however, increased with the increase in the size of litter farrowed up to 12, when nine pigs were raised.

BIRTH WEIGHT OF PIGS

Birth weight related to death losses. Generally speaking, the heaviest pigs in the litter are the strongest and the smallest the weakest. Data collected under the direction of E. Z. Russell [22] of the Bureau of Animal Industry at five U.S. Animal Husbandry Stations from 1927 to 1931, inclusive, show that the birth weight is related to the percentage born dead and the percentage weaned, as shown in Table 28.

There were 7749 pigs involved in this study. The average percentage farrowed dead for all classes was 7.54 and the average percentage

[20] A. Severson, *Proc. Am. Soc. An. Prod.*, 1925–26.
[21] J. L. Lush, *The Cattleman*, Feb., 1933.
[22] *The Extension Animal Husbandman*, U.S.D.A., 1933.

Table 28. Pigs Farrowed and Percentage Farrowed Dead and Weaned

Birth Weight (Lb.)	*1*	*1 to 1½*	*2*	*2 to 2½*	*3*	*3 to 3½*	*4*
Number farrowed	160	543	1422	2064	2120	1059	381
Percentage farrowed dead	39.38	15.84	9.42	6.30	6.03	3.12	4.46
Percentage weaned	5.00	30.20	55.98	68.22	74.20	79.03	83.46

weaned was 66.1. In a study of the records of 6401 pigs farrowed in the Indiana Station herd, Vestal got results which paralleled exactly those shown in the table. The average percentage farrowed dead in this study was 5.16 and the average percentage weaned was 65.96.

Vestal of the Indiana Station [23] reports data which supply further evidence of the handicap carried by pigs which are undersized at birth. In Table 28 are the records collected from 784 spring litters and 7554 pigs.

Table 29. The Effect of Weight at Birth on Development of Pigs from Birth to Weaning

Birth Weight	*Number Pigs Farrowed*	*Percentage Born Dead*	*Percentage Weaned*	*Average Weaning Weight*
lb.				lb.
1.00	56	46.43	0.00	0.00
1.25	107	14.02	1.87	8.63
1.50	270	15.93	12.96	18.42
1.75	291	7.90	34.02	19.97
2.00	674	6.08	49.26	20.91
2.25	832	4.33	63.34	22.78
2.50	1531	4.38	67.40	24.49
2.75	1157	3.54	74.16	26.24
3.00	1354	4.14	77.32	27.50
3.25	587	2.73	82.45	29.39
3.50	426	3.05	85.68	30.22
3.75	143	2.80	83.91	30.86
4.00	93	1.08	83.87	34.72
4.25	28	3.57	85.72	36.72
4.50	2	0.00	100.00	30.00
4.75	3	0.00	100.00	38.67

Birth weight related to weaning and market weights. Not only are the losses of underweight pigs greater than for those of normal weight, but such pigs do not have the ability to gain during the nursing period.

[23] C. M. Vestal, Bul. 413, 1938.

According to these data, a difference of ½ pound in weight at birth meant, on the average, a difference of 4.68 pounds at weaning time.

That birth weight is related to market weight as well as weaning weight is shown in Table 30.[24]

Table 30. Average Daily Gain of Pigs from Birth to Market as Related to the Birth Weight

Birth Weight (lb.)	*1 to 1½*	*1½ to 1¾*	*1¾ to 2*	*2 to 2¼*	*2¼ to 2½*	*2½ to 2¾*
Number farrowed	26	37	162	167	321	200
Average daily gain, suckling period (lb.)	0.38	0.44	0.46	0.50	0.52	0.52
Average daily gain, fattening period (lb.)	1.18	1.20	1.23	1.27	1.32	1.32

Birth Weight *(Lb.)*	*2¾ to 3*	*3 to 3¼*	*3¼ to 3½*	*3½ to 4*	*4+*
Number farrowed	250	101	93	37	35
Average daily gain, suckling period (lb.)	0.56	0.56	0.62	0.65	0.63
Average daily gain, fattening period (lb.)	1.35	1.36	1.43	1.43	1.44

Calculations from these data indicate that a difference of ½ pound in birth weight resulted in a difference of 2.6 pounds at weaning time; and that a difference of 2.6 pounds at weaning time meant a difference of 7.1 pounds when 160 days old.

Studies by Weaver and Bogart of the Missouri Station [25] in connection with the Regional Swine Breeding Laboratory from 1938 to 1942 also supply data showing the relation of birth weight to weaning and market weights. At this station an advantage of ½ pound in birth weight was equivalent to a difference of 4.2 pounds at weaning time; and a difference of 4.2 pounds at weaning time resulted in a difference of 7.5 pounds at 6 months of age.

It would seem safe to conclude from these investigations that the birth weight of a pig is quite closely related to its weight both at weaning and market time. On the average, a difference of ½ pound in birth weight may be expected to result in a difference approximately of 3 to 5 pounds at weaning, and a difference of 7 to 8 pounds at market time.

The average weight of pigs at birth is approximately 2½ pounds,

[24] E. Z. Russell, *Extension Animal Husbandman*, U.S.D.A., 1933.
[25] L. A. Weaver and Ralph Bogart, Bul. 461, 1943.

but there is a wide range of variation. There are a number of influences which may be responsible for these differences. Some of the important factors are (1) sex; (2) age of the mother; (3) crossbreeding; (4) size of litter; (5) vigor of parents; and (6) nutrition during foetal growth.

Sex. Boar pigs are slightly heavier on the average than sow pigs, as are the males of the other species of farm animals. Of 5287 pigs farrowed in the college herds of Illinois and Purdue, there were 2720 boars and 2567 sows. The average birth weight of the boars was 2.58 pounds and of the sows 2.50 pounds.

Age of sow. The effect of the age of the sow on the birth weight of the individual pigs is shown by studies of Carmichael and Rice of the Illinois Station [26] which are shown in Table 31.

Table 31. Effect of Age on Sow on Birth Weight of Pigs

Age of Sow, Years	*Total Number of Pigs*	*Average Birth Weight of Pigs*
1	922	2.44 lb.
1½	826	2.48 "
2	899	2.56 "
2½	570	2.54 "
3	455	2.59 "
3½	299	2.66 "
4	293	2.56 "
4½	166	2.70 "
5	92	2.87 "

The data of Russell [27] showed an average birth weight of 2.65 pounds for pigs produced by 42 mature sows, 2.58 pounds for those farrowed by 44 gilts that had mature sows for mothers, 2.62 pounds for the pigs produced by 43 gilts whose dams were gilts. Records of 439 spring litters farrowed by sows and 213 spring litters farrowed by gilts at the Indiana Station [28] showed a birth weight approximately of 2.73 pounds for the pigs farrowed by sows and 2.46 pounds for those farrowed by gilts.

It would appear from all these figures that mature sows produce on the average heavier pigs than do gilts, although, as we have seen, they also produce a larger number per litter. The difference, however, is small and does not mean that pigs from gilts are materially handicapped.

[26] W. J. Carmichael and John Rice, Bul. 226, 1926.
[27] E. Z. Russell and R. E. Hutton, U.S.D.A., Cir. 472, 1938.
[28] C. M. Vestal, Bul. 413, 1936.

Crossbreeding. Lush and associates of the Iowa Station [29] report birth-weight records of 35 litters each of which contained both purebred and crossbred pigs, the result of double-mating. Purebred or practically purebred sows were mated with boars of their own breed and with one of another breed in the same heat period. Differences in color markings enabled the hogmen to distinguish the purebreds from the crossbred pigs. The breeds used were Poland China, Duroc Jersey, and Yorkshire. In these 35 litters there were 174 purebred and 188 crossbred live pigs, the purebreds averaging 2.86 pounds at birth and the crossbreds 3.07 pounds.

Using the system of double-mating Poland Chinas and Duroc Jerseys, and pairing the sexes of the crossbred and purebred pigs to eliminate the sex factor on weight, Roberts and Carroll of the Illinois Station [30] found an average birth weight of 2.63 pounds for the purebred pigs, 2.76 pounds for the crossbreds. This study also revealed the interesting facts that, of the 65 mixed litters farrowed, 359 pigs were sired by the boar used first and 279 by the boar used last; and in these same litters 329 of the pigs were purebred and 308 crossbred.

Carroll and Roberts of the Illinois Station,[31] considering only those experiments in which the crossbreds were compared with the purebred pigs produced by parent breeds, found the birth weights of the crossbreds to be intermediate between that of the purebreds produced by the two respective parent breeds. When the averages were based on the results from the individual experiments, the purebred pigs produced by the heavier pig-producing breed had an average birth weight of 2.90 pounds; the purebred pigs produced by the lighter producing breed had a birth weight of 2.65 pounds, while the crossbred pigs had an average birth weight of 2.79 pounds. In this study 5904 purebred and 6137 crossbred pigs were involved.

Based on 6 years of crossbreeding studies, Winters and associates of the Minnesota Station [32] report an average birth weight of 2.55 pounds for 715 purebreds produced by the breeds involved in crossing, and 2.60 pounds for 440 crossbreds (first cross).

Size of litter. That the number of pigs contained in the litter is one of the more important factors affecting the birth weight of the individual pigs is indicated by all the records that have been reviewed. This is well illustrated by data from the Indiana Station herd as ar-

[29] J. L. Lush, P. S. Shearer, and C. C. Culbertson, Bul. 380, 1939.
[30] E. Roberts and W. E. Carroll, *Jr. of Agr. Res.*, Vol. 59, No. 11, 1939.
[31] W. E. Carroll and E. Roberts, Bul. 489, 1942.
[32] L. M. Winters, O. M. Kiser, P. S. Jordan, and W. H. Peters, Bul. 320, 1935

ranged by Vestal.[33] These records are from 439 litters produced by sows, and 210 litters produced by gilts, as shown in Table 32.

Table 32. Effect of Size of Litter on Birth Weight of Pigs

Number of Pigs per Litter	*Number of Litters*		*Average Birth Weight of Pigs*	
	Sows	*Gilts*	*Sows*	*Gilts*
			lb.	lb.
6	11	28	3.14	2.66
7	28	27	2.87	2.52
8	44	41	2.75	2.60
9	46	30	2.83	2.49
10	70	28	2.75	2.37
11	59	32	2.63	2.33
12	72	20	2.60	2.46
13	45	4	2.71	2.23
14	34		2.51	
15	30		2.57	

Although exhibiting some irregularity, the data show a rather clear trend of a decrease in birth weight of the individual pigs as the number of pigs in the litter increases.

Vigor of sow and boar at breeding time. That there is a casual relation between the vigor of the parents at breeding time and the vigor and development of their offspring is attested by the observation of stockmen and the results of laboratory experiments. Animals which are in a state of vigorous health at breeding time produce germ cells endowed with the maximum of vigor and growth energy; while those in a run-down, weakened, or unthrifty condition produce germ cells which lack the life necessary for the conception of vigorous young.

Each pig is the product of two germ cells, one produced by the sow and one by the boar. Sows in a state of extreme fatness at breeding time, especially if confined to limited quarters, do not produce, as a rule, strong pigs. Likewise, if the breeding condition of the boar is at low ebb, as a result of insufficient or excessive feed, lack of exercise, overuse, bad heredity, or disease, his germ cells, like those of the sow, may lack the life necessary to ensure vigorous, well-developed pigs at birth. It is reasonable to conclude that one of the causes responsible for small weak pigs is the practice of breeding the sows when they and the boar are not in normal breeding condition.

Nutrition. One of the fundamental factors determining the size and

[33] C. M. Vestal, *Bul. 413, 1938.*

development of pigs at birth is the completeness of their nourishment during embryonic development. This will be mainly determined by the nutritional state of the sow and the adequacy of the ration fed her during the gestation period. Although the sow, if in strong condition when bred, is generally able through the use of her own body reserves to bring her embryo litter to normal maturity when on a deficient ration, the pigs at birth will not be as large and well developed as when the food supply is adequate. When the ration during the gestation period is seriously lacking in protein, minerals, or vitamins, as is not uncommon in the Corn Belt, the effect, especially when the sow is thin to begin with, is likely to be an increase in the number of dead pigs as well as underdevelopment.

The pigs in abnormally large litters are ordinarily not so well developed as are those in normal-sized litters (see Table 32). This, it seems reasonable to suppose, is due to the inability of the foetal membranes to accommodate and properly nourish the extra number. As a rule, sows which bring forth two litters a year, also, do not produce as large pigs as they do when farrowing but once.

MILK PRODUCTION OF SOWS

There is but limited information available relative to the milk-secreting capacity of the sow. This is because her production must be determined indirectly; *i.e.*, by keeping the sow and litter separate during the test periods and weighing the pigs immediately before and immediately after nursing. In Table 33 there is presented a summary of the data for 59 sows compiled by Hughes and Hart of the California Station,[34] together with records obtained from studies made of the production of three sows in the Illinois Station herd and of nine in the Purdue University herd.

Table 33. Milk Production of Sows

Number of Sows	*Average Number of Pigs in Litter*	*Average Daily Production*	*Calculated Production during Lactation*		
			8 Weeks Duration	*10 Weeks Duration*	*12 Weeks Duration*
		lb.	lb.	lb.	lb
59	7.9	6.8	413	447	465
12	9.8	6.0	336	420	504
Average 71	8.2	6.67	374	467	560

[34] E. H. Hughes and H. G. Hart, *Jr. of Nut.*, Vol. 9, No. 3, 1935.

Olofsson and Larsson of the Svalov Experiment Station, Sweden,[35] studied the milk production and feed consumption of 200 sows of the Large White breed for periods of 6 to 8 weeks during the nursing period. They reported the surprisingly high average production of 10.36 pounds of milk daily from the second to the eighth weeks of lactation. The method used in determining the milk production was the same as that employed in the tests already referred to. During the experimental period, the sows consumed the equivalent of 13.6 feed units, or pounds of concentrates, daily. At the end of the nursing period of 8 weeks, 40 percent of the food requirements of the pigs was being supplied by the mother's milk.

German investigators[36] determined the milk flow of 11 Mangalitza sows, mostly over 4 years of age, and of six young Large White sows over a period of 8 weeks. The average daily production of the sows of the Mangalitza breed was 5.68 pounds, and of the Large White breed 7.13 pounds. The milk yield was found to vary with the number of pigs in the litter and with the age of the sows. Maximum production occurred during the third or fourth week of lactation, following which time there was a general decline.

Hammond of the University of Cambridge[37] after summarizing European data places the average production in an 8-week lactation period at about 370 pounds, equivalent to an average daily production of 6.6 pounds. Maximum daily production of 8.57 pounds was reached during the third week of lactation, after which there was a gradual decline to a minimum of 4.28 pounds daily during the eighth week.

There was considerable variation in the amount of milk given by the sows whose average records are shown in Table 33, the extreme range being from 3.4 to 11.6 pounds daily. A systematic study of the individual records of 23 of these sows revealed some interesting facts relative to the causes of this variation.

The age of the sow apparently is a factor which affects milk production. The five yearling sows in this group produced an average of 5.14 pounds of milk daily; eight 2-year-olds produced 5.39 pounds daily; four 3-year-olds, 5.49 pounds daily; three 4-year-olds, 8.10 pounds; and three 5-year-olds, 5.41 pounds daily. That most of the variation was due to differences in the individualities of the sows rather than age, however, is indicated by the fact that among the five

[35] *Exp. Sta. Record*, Abstract, Vol. 67, No. 1, 1932.
[36] *Exp. Stat. Record*, Abstract, Vol. 79, p. 233, 1938.
[37] John Hammond, *Farm Animals*, Longmans, Green & Co., London, 1940, p. 94.

yearlings the heaviest milk flow exceeded the lightest by 83 percent, and among the eight 2-year-olds the difference was 115 percent. Apparently there is as much variation among sows as there is among cows in the ability to secrete milk and the same opportunity exists, therefore, to improve them in this valuable trait by selection.

As a rule, the sows which farrowed the largest litters produced the heaviest milk flow. The 13 sows which farrowed eight or more pigs to the litter produced an average of 6.60 pounds of milk daily, while those which farrowed but seven or less pigs to the litter produced 4.54 pounds on the average. That a high degree of correlation should exist between two such intimately associated functions seems reasonable. Fertility and milk-producing capacity are in fact expressions of a common function.

The amount of milk given by a sow seems to be related also to the loss of weight which she normally experiences during the suckling period. In the cases here considered, weights were taken as soon as the sows had recovered from farrowing and again when their litters were weaned. The 10 sows which produced 7 or more pounds of milk daily lost an average of 59 pounds in weight during the suckling period; seven sows which produced between 5 and 7 pounds lost 23 pounds; and the five which produced less than 5 pounds of milk daily lost an average of 25 pounds. Although the number of sows in each group here is limited, the results nevertheless are suggestive.

With 11 of the sows, the milk flow was determined for each of the 8 successive weeks of the nursing period. The average production for the first week was 5.01 pounds, on the average; for the second week, 7.46 pounds; the third week, 8.40 pounds; the fourth week, 7.80 pounds; the fifth week, 5.72 pounds; the sixth week, 5.77 pounds; the seventh week, 4.65 pounds; and the eighth week, 3.24 pounds. The individuals departed little from these averages. All but two of the sows produced their maximum during the second, third, or fourth week of lactation. With but one exception, all produced their lightest flow the seventh or eighth week. The activity of the milk-secreting glands seems to reach its maximum 3 or 4 weeks after farrowing and then declines, at first gradually, and then quite perceptibly during the seventh and eighth weeks.

The amount of milk which a sow gives is influenced largely by her care and feeding. In order to produce her maximum milk flow, she must be provided with the raw materials with which to manufacture it. The ration, therefore, which is rich in milk-producing properties

and is fed in liberal amounts is the one which will stimulate and make possible the full production capacity of each individual sow (see page 98). That her milk production also bears some relationship to her age, the number of pigs which she farrows, and her tendency to "milk down" during the suckling period is attested by the evidence just reviewed.

To the critically inclined it is obvious that the indirect method of determining milk production can give at best only approximations. The amount of milk given by the sow under normal nursing conditions exceeds, no doubt, the amount taken by the pigs during an experimental test period. No method has yet been devised which would enable one to make directly a complete drawing of all the milk. Furthermore, it is probable that a sow will secrete less milk when the litter is limited in size, say to five pigs and five teats nursed, than she will with a full litter when all her teats or udders are functioning. The amount of milk given by sows with large litters usually exceeds the amount given by sows with small litters. It is reasonable to conclude that this difference is due as much to the larger number of udders in use as it is to a difference in the inherent milking capacity of the two classes of sows.

COMPOSITION OF SOW'S MILK

In Table 34 are reported available American data showing the composition of sow's milk as determined from samples taken from 53 sows. There is included also the composition of the colostrum or first milk, the samples having been taken during and up to 40 hours after farrowing.

Table 34. Composition of Sow's Milk

Number of Sows	*Total Solids*	*Fat*	*Protein*	*Sugar*	*Ash*	*Source of Data*
	%	%	%	%	%	
22	18.88	6.64	5.81	5.47	0.96	Wis. Station
28	17.96	5.35	6.32	5.35	0.94	Calif. Station
3	19.86	5.83	6.34	6.65	1.04	Purdue Univ.
Average 53	18.45	5.91	6.11	5.48	0.95	
Colostrum 20 sows	28.23	5.29	14.77	7.53	0.64	Calif. Station
Cow's milk	12.80	3.70	3.50	4.90	0.70	Morrison

In similar studies at the Wisconsin Station, Bowland and associates [41] found that the amount of vitamin A stored in the liver of sows was related to the vitamin A content of their diet, and that the amount of vitamin A in their milk, particularly in the colostrum, was related to the amount of liver storage. Spring-produced milk was found to be much lower in vitamin A than that produced in the winter.

Parrish and associates of the Kansas Station [42] found a tendency for the vitamin A levels in the colostrum and the blood serum of new-born and 5-day-old pigs to reflect the vitamin A levels in the sow's blood at time of farrowing. There appeared to be little relationship between the vitamin A content of sow's blood and that in the livers of new-born or 5-day-old pigs.

SEX RATIO IN PIGS

In Table 35 are brought together available statistics on the proportion of males to females among pigs at birth. These figures are based on actual herd records as reported by different investigators and do not include data from herdbooks. Studies by McPhee have thrown some doubt on the reliability of the data collected from the latter source.

Table 35. Ratio of Male to Female Pigs

Authority	*Pigs of Both Sexes*	*Male Pigs*	*Female Pigs*
McKenzie [a]	2011	1034	977
Sinclair and Syrotuck [b]	2533	1360	1173
Carmichael and Rice [c]	5657	2933	2724
Crew [d]	1472	736	736
Severson [e]	3779	1976	1803
McPhee [f]	7854	4083	3771
Lush [g]	3639	1861	1778
Grand Total	26,945	13,983	12,962

[a] Mo. Exp. Sta., Research Bul. 118, 1928.
[b] *Sci. Agr.*, Vol. 8, No. 8, 1928.
[c] Ill. Exp. Sta., Bul. 226, 1920.
[d] *Proc. Royal Soc. of Edin.*, Vol. 46, Part 1, 1925–1926.
[e] *Proc. Am. Soc. An. Prod.*, 1925–1926.
[f] Hugh C. McPhee, *Jr. Agr. Res.*, Vol. 34, p. 715, January–June, 1927.
[g] Jay L. Lush, H. O. Hetzer, and C. C. Culbertson, *Genetics*, Vol. 19, No. 4, July, 1934.

[41] J. P. Bowland, Li-min Wu, R. H. Grummer, P. H. Phillips, and G. Bohstedt, *Jr. An. Sci.*, Abs., Vol. 8, No. 4, 1949.
[42] D. B. Parrish, C. E. Aubel, J. D. Wheat, and J. S. Hughes, *Jr. Agr. Sci.*, Abs., Vol. 8, No. 4, 1949.

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[e] *Proc. Am. Soc. An. Prod.*, 1925–1926.
[f] Hugh C. McPhee, *Jr. Agr. Res.*, Vol. 34, p. 715, January–June, 1927.
[g] Jay L. Lush, H. O. Hetzer, and C. C. Culbertson, *Genetics*, Vol. 19, No. 4, July, 1934.

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[42] D. B. Parrish, C. E. Aubel, J. D. Wheat, and J. S. Hughes, *Jr. Agr. Sci.*, Abs., Vol. 8, No. 4, 1949.

These data give a sex ratio of 51.89 percent males.

In this connection it is interesting to note that studies by Crew and Parkes, previously noted, revealed that the primary sex ratio, that is, the ratio existing among the newly fertilized eggs, is about 150 males to 100 females, or 60 percent males. Owing to the fact that 30 to 40 percent of the eggs or foetuses perish before birth and that this mortality falls more heavily on the males than the females, the ratio swings back near to equality at birth (see page 117).

VI Housing and General Management of the Breeding Herd

In this chapter consideration will be given to the general problems of housing, lotting and grading, exercise, and sanitation involved in the successful management of the breeding herd which cannot be considered more appropriately later in connection with the separate divisions of the subject.

HOUSING

The hog more than any other farm animal is sensitive to the extremes of heat and cold. Although, when well fed, he carries a considerable layer of fat under the skin his thin hair coat provides little natural protection against cold or heat; and due to the fact that he is without sweat glands, except in the snout, he is deprived the cooling effect of water evaporation from the body surface in hot weather. Young pigs, largely because of greater surface area for their size and less fat, require higher temperatures for their comfort and well-being than do older hogs. Also, pigs which are receiving full rations, due to greater internal heat production, are better able to stand low temperatures than fasting pigs or those fed a maintenance ration.

Heitman and Hughes of the California Station [1] in recent important studies of the effects of temperature and humidity on the well-being of swine, found that fattening hogs of weights from 70 to 144 pounds perform most efficiently in a temperature of 75°F; and at weights from 166 to 260 pounds, when the temperature is approximately 60°F. When the air temperature was increased or decreased, the rate of gain declined and utilization of food was lowered.

In the northern latitudes especially, warm houses are necessary during the winter in order to save feed and maintain thrift. In the South, the chief problem is that of providing the conditions which will

[1] Hubert Heitman, Jr., and E. H. Hughes, *Jr. An. Sci.*, Vol. 8, No. 2, 1949.

protect against high temperatures and excessive humidity. All classes of hogs must have comfortable quarters in order to do well. This is a principle in livestock management which no farm can afford to ignore.

Extent of housing facilities required. The problem of providing practical and suitable housing for the herd is always a real one on the hog farm. The extent of the facilities required will be determined mainly by the number of pigs, both spring and fall, which are to be produced annually, by the general type or plan of feeding and management which it is proposed to follow, and the geographical location of the farm. In too many instances farms are inadequately equipped for the number of hogs handled, and in other cases there is a costly over-

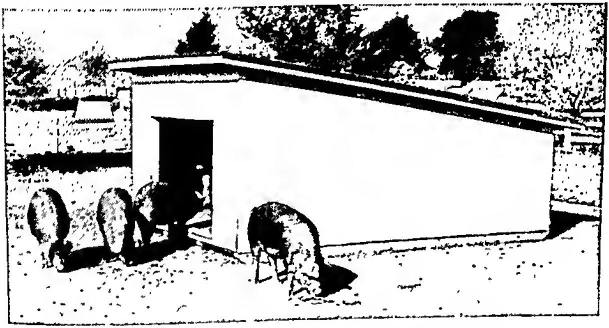


Fig. 26. A portable 10 by 12 open-front house adapted for winter or summer use for all classes of hogs *(Ind. Exp. Sta.)*.

investment in buildings. A satisfactory solution of this point can be determined only when a well-considered plan of production for the farm has been worked out and adopted, and then by adhering fairly closely to this plan from year to year. Such a plan is desirable for several important reasons, one of which is that it makes possible the efficient use of the equipment available.

In the latitude of the Corn Belt the following suggestions regarding the extent of the housing equipment required for different conditions are appropriate:

1. On those farms which produce only spring pigs, which are farrowed by gilts of the previous year's crop, the mothers being fattened

and sold as soon as their pigs are weaned, there will be required the equivalent of about one individual house for each litter farrowed, or one house for each sow farrowing a litter, plus one house for the boar. This will be adequate whether the pigs are farrowed early or late in the spring and regardless of the method of feeding and time of marketing, except that the pigs must be off to market before the next farrowing season.

2. Where the two-litter system of production is followed, half to two-thirds produced by mature sows and the remainder by gilts, and when the pigs are farrowed mostly in March and September and fed full rations so that they leave the farm before the next farrowing season, the requirements will be at the rate of about one and one-half individual houses for each two litters farrowed, plus one house for the boar. This would make the housing needs for this system of production about 75 percent of those in the single-litter system, number of pigs produced considered. It is to be noted, however, that it is more imperative that a good house be available for the early-farrowing sow than is often considered necessary for the late-farrowing one.

The central and individual house compared. There are two general systems in housing hogs. In one the individual or colony house is used, and in the other a single large house centrally located. A combination of these two is often found which might be designated as a third system. Each of these systems has its advantages. Considering the matter of efficiency with which the seasonal needs of the various classes of hogs on the farm are taken care of, economy of construction, labor and fencing requirements, the problem of health maintenance, etc., the following points favorable to each system may be enumerated:

1. The individual or colony house is portable and can be moved from place to place. This is its most valuable characteristic. Through it better management and feeding practices are made possible and encouraged. The brood sow and her litter can be kept on clean fresh pasture and away from worm-infested lots; the hogs can be rotated with the crops. This means more healthy pigs, less loss from diseases and parasites, lower feeding costs, as well as fertility benefits to the soil.

2. The colony house is especially better adapted to the rented farm because it is possible for the renter who is compelled to provide his own equipment to take it with him when he moves. In case the landlord has supplied more equipment than the renter can or is in-

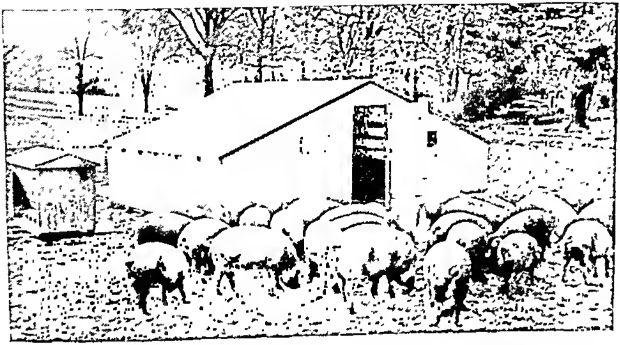


Fig. 27. This type of portable house, in two sections, has become quite popular in the Corn Belt *(courtesy, Ind. Exp. Sta.; photo by Allen).*

clined to use, it can be sold. Overequipment is less likely when the colony rather than the centralized type is used.

3. The individual house is more economical, especially for the small farmer or beginner whose ability to make money with hogs has not been tested, or who has not had the experience to determine just how large the swine enterprise for his particular farm should be. Also, skilled labor is more necessary in the construction of the central house than for the small colony type. The latter can be made by the farmer himself during the winter and at other odd times. He will thus more likely provide the equipment as it is needed, increasing it gradually as the herd grows, and in line with the principle of allowing the herd to grow only on its own profits.

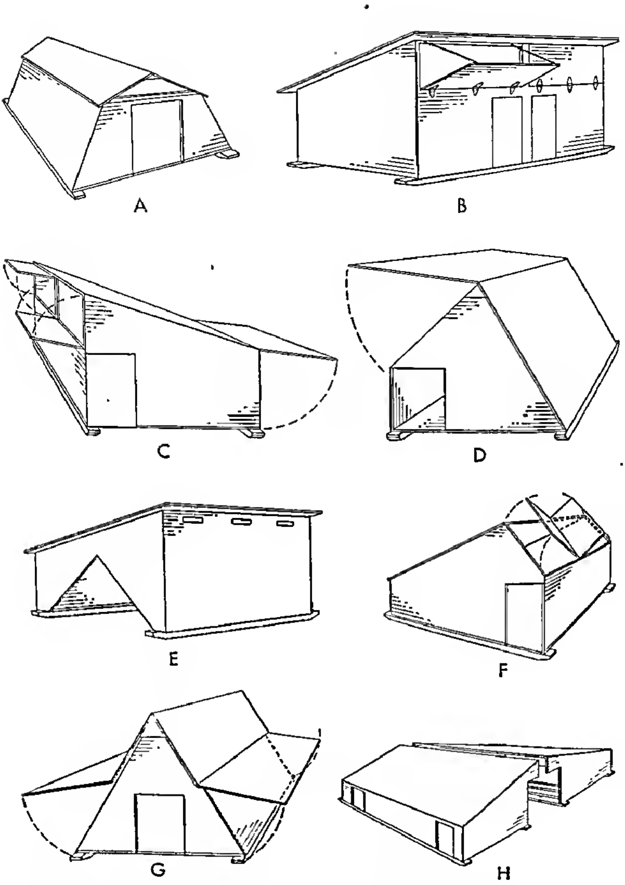


Fig. 28. These line drawings illustrate types of individual or portable houses found in use on American hog farms.

groups at outlying points. Perhaps the last point is not so important, for the reason that the individual houses may be and often are centrally located during the cold season. It should also be stated that the individual house when banked with straw or corn stalks is as comfortable as the unheated central house.

1. One of the most important advantages of the centralized housing system is that it permits more effective supervision and care of the sows and young pigs at farrowing time. With early farrowing, this close contact which is possible is a matter of considerable importance in saving the pigs in cold weather. The central house, or a few pens partitioned off in one section, can be heated artificially more easily than can the individual farrowing house. Sows that are restless, irritable, or cross can be more successfully managed. The job of removing the needle teeth and notching the ears can be done with less disturbance and trouble. It is possible to revive chilled pigs more promptly, to assist weak pigs to the teat, and to give that constant observation and care which is all-important during the first week of the pig's life.

2. Another advantage which the large central house has over the individual house is that less labor is required in the feeding and care of the herd. The feed and water supply is close at hand and the herd mostly under one roof. The work of castrating, vaccinating, dipping, ringing, and breeding can be more systematically and easily managed.

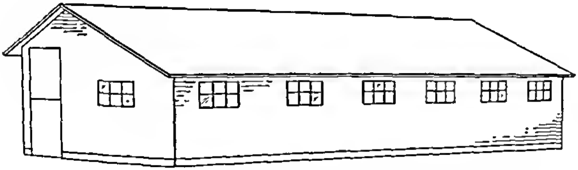


Fig. 29. An inexpensive and efficient type of central farrowing house.

Less general equipment, also, such as troughs, barrels, water fountains, etc., is necessary.

3. The central type of house is more substantial in construction and usually gives longer service. With concrete floors and foundation, the building is ratproof and the floors can be cleaned and disinfected with a minimum of labor. It has some special advantages for the breeder of pedigreed hogs. It facilitates the classification and display of the

pigs which are for sale and is a great convenience in the conduct of auctions.

The principal disadvantage of the centralized type of housing is that it encourages a centralized type of management, thus making more difficult the problem of controlling parasites, especially worms, and that there is difficulty in providing the clean outside conditions which are so essential in the prevention of severe anemia among the young pigs. It is not adaptable to the needs of the herd managed according to the best-known principles. A second objection to the large central house is its cost. Too often it is pretentious in design, elaborately equipped, and larger than needed.

Conclusions. A fair consideration of the advantages and disadvantages of the two systems of housing just discussed points rather definitely to the conclusion that the best and most practical plan is the one which places most reliance on the individual house, but supplemented with a small centrally located building to be used as a farrowing house or "lying-in hospital" when early pigs are produced. This should be of a capacity to supply farrowing accommodations for about one-fourth the sows in the herd. The sows that have farrowed may be moved out to their individual houses as it is necessary to provide accommodations for those soon due. In this combination plan we have practically all the advantages, and none of the serious disadvantages, of both systems.

LOTTING AND GRADING

Good management and feeding results are not possible when all the classes of hogs, both big and little, are allowed to run together more or less promiscuously. Only those individuals whose requirements for feed and care are the same should be together. The effect, for example, of allowing the pregnant sows to run with the fattening shotes is to jeopardize the chances of a good pig crop later as well as to increase considerably their cost of maintenance. Hogs that are being fattened do well in restricted quarters and with full fattening rations. It is not possible under these conditions for pregnant sows to perform satisfactorily; they demand a limited ration and plenty of exercise. The bred gilts should likewise be separate from the mature sows, for they cannot compete successfully with the older sows at the trough or sleeping quarters.

The practice of allowing the pregnant sows or gilts to run with the breeding cattle is not objectionable so long as separate sleeping quar-

ters are provided and the consumption of corn is carefully guarded. Horses should not be allowed in the same field with the sows because the chances of injury are too great. The mature boar should occupy independent quarters from the boar pig unless they can be fed separately. The boar is often allowed to run with the bred sows which is not objectionable so long as he behaves himself. It will facilitate his care and greatly improve his opportunity for needed exercise and companionship.

The number of lot divisions necessary at central headquarters for the accommodations of the herd during the winter period will depend mainly on whether fall pigs are produced and the time the spring pig crop is marketed. Under most conditions, when both fall and spring pigs are produced, six to eight lots in addition to the boar lot will be needed. These should not be of the "dry-lot" variety; they should grow at least one and sometimes two forage crops a year. For handling 75 spring and 50 fall market pigs, an area of an acre and a half, twice as long as wide, divided the long way into six lots with pigtight woven wire fence, will be adequate. These should be used to supplement rather than to replace forage feeding in the field during the summer, and for lotting and grading purposes during the winter. There should be no more than one dry lot at the barn and this of minimum dimensions, partly concreted, to be used as a holding and sorting pen and for feeding out market pigs in cold weather.

EXERCISE

A reasonable amount of regular exercise is an important factor in the maintenance of breeding thrift in all mature animals and in promoting vigor and health in young growing animals. Breeders believe that the amount of exercise taken by the sow during the gestation period bears some relationship to the strength and activity of her pigs at birth and to her ability to farrow her pigs without difficulty or complication. In connection with this point it will be interesting to consider some recent experimental studies which have been made.

Some experimental studies. Results of trials by Anderson and Marston of the Kansas Station [2] indicate that the size of the exercise yard given pregnant gilts during the winter has an important bearing on the vigor of the pigs at birth and the thrift and weight of the pigs when one month of age. They gave four gilts during the gestation period a large yard, in which no vegetation was allowed to grow, while

[2] B. M. Anderson and H. W. Marston, Cir. 118, 1925.

the same number was confined to a small pen 8 by 6 feet in dimensions. Liberal quantities of earth were taken from the large and put into the small pen so that the available mineral supply would be more nearly the same. Half of the gilts in each group were fed corn alone and the other half corn and tankage. The results are briefly summarized in Table 36.

Table 36. Showing Value of Exercise for Pregnant Gilts

Treatment	*Ration*	*Weight of Pigs at Birth*	*Weight of Pigs at 1 Month of Age*
		lb.	lb.
Exercise	Corn alone	1.97	11.75
	Corn and tankage	2.07	14.08
No exercise	Corn alone	1.97	7.67
	Corn and tankage	1.90	11.84

During the gestation period it was observed that the sows which had the opportunity to exercise "were smoother of hair coats" than those not getting exercise. The authors reported also that although the sows which received no exercise and corn alone farrowed as heavy pigs as those receiving the same ration with exercise, the pigs were listless and inactive, several were born dead, and some undeveloped and with little hair. The pigs from both ration groups of sows which received liberal exercise developed more rapidly and showed decidedly more thrift than those from dams not getting exercise.

Under somewhat different conditions, Hogan of the Missouri Station [3] made a test to determine the possible effect which exercise might have on some of his experimental feeding results with pregnant sows kept under conditions of close confinement. One group of six sows was systematically exercised by driving them up and down a long hallway. From September 10, 1926, to March 26, 1927, they were compelled to walk a distance of a mile each day. As they became heavier with pig, the distance was reduced. On March 26 it was reduced to three-fourths of a mile a day, and on April 26 to one-fourth of a mile. Another group of seven sows, fed the same ration and housed under the same conditions, were not exercised; they were rather closely confined. Both groups were inside on board or concrete floors the entire time. The number of dead pigs farrowed per litter was 0.33 for the sows which received exercise, and 1.14 for those which

[3] A. G. Hogan, Res. Bul. 168, 1932.

received no exercise; in the weights of the individual pigs and of the litters at weaning, there were no significant differences.

In feeding experiments with sows and gilts, Vestal of the Indiana Station [4] devised the scheme of dividing each ration group into two lots, one of which was allowed liberal exercise and the other limited exercise. A further division was made which permitted a study of the effects of exercise as influenced by the condition of the sows. The feeding trials covered five winter gestation periods, from 1920–1921 to 1925–1926, and involved the use of 108 mature sows and 36 gilts. The sows with liberal exercise had the run of dirt lots approximately 100 yards in length, the sleeping quarters being located at the far end, while those with limited exercise were confined to similar dirt lots about 30 feet square in area. These conditions were maintained until the pigs were weaned, but all groups received the same milk-producing ration during the suckling period. The data as arranged in Table 37 make possible a comparison also of the results as affected by the condition of the sows.

Table 37. Effect of Large and Small Exercise Yards during the Gestation Period

	Liberal Exercise			*Limited Exercise*		
	Medium Condition	*Fat Condition*	*Average and Totals*	*Medium Condition*	*Fat Condition*	*Average and Totals*
Number of sows that farrowed	38	38	76	36	35	71
Number of sows that weaned litters	38	35	73	32	31	63
Number of pigs per litter	8.43	8.96	8.69	9.51	9.03	9.28
Birth weight per pig	2.71 lb.	2.58 lb.	2.61 lb.	2.55 lb.	2.56 lb.	2.55 lb.
Vigor of pigs						
Strong	71%	61%	67%	65%	58%	61%
Medium	17%	22%	20%	19%	22%	20%
Weak	8%	10%	9%	12%	10%	12%
Dead	4%	4%	1%	4%	10%	7%
Number of pigs in weaned litters	6.33	5.32	5.85	5.89	5.37	5.63
Percentage of farrowed pigs weaned	71%	55%	61%	62%	55%	58%
Weight of litter at weaning time	173 lb.	142 lb.	157 lb.	149 lb.	135 lb.	142 lb.
Weight of each pig at weaning time	27 lb.	27 lb.	27 lb.	26 lb.	24 lb.	27 lb.

It may be a matter of surprise to some that the effect of exercise as shown in these results was not more pronounced. Perhaps the most significant difference was in the number of litters lost after farrowing.

[4] C. M. Vestal, Bul. 413, 1935.

There were three sows in the exercise group which lost all of their pigs before weaning time, and eight in the limited-exercise group. Most of these, it is of some importance to observe, were in the lots where the sows were allowed to become excessively fat. Although the sows with limited exercise farrowed larger litters, the general results showed that those with liberal exercise had a slight advantage in weight of pigs at birth, strength at birth, percentage of farrowed pigs weaned, and in total litter weight at weaning time.

Considering only the lots which were fed for medium condition of flesh, the effects of the difference in exercise were more evident. Those getting liberal exercise were significantly better in the number of farrowing sows which weaned litters, the number of pigs farrowed, the percentage of farrowed pigs weaned, and the weight of the litter at weaning time.

In the case of the sows which were allowed to become excessively fat, exercise, or rather the opportunity to exercise, had no significant influence apparently. It may have been that the fat condition of the sows did not permit as much differentiation in the actual amount of exercise taken as the difference in the size of the lots suggests. Due to their condition, in other words, the sows in the larger lots may have taken little more exercise than did those in the smaller lots.

Conclusions and discussion. The fact that the exercise taken, or the opportunity to exercise, did not have more noticeably beneficial effects in the case of the pregnant sows studied in some of these experiments probably does no more than show the difficulty of measuring such benefits. The health-promoting benefits of a reasonable amount of regular exercise for pregnant animals is so well established that the experienced stockman would not allow it even to be seriously questioned.

It probably is true, nevertheless, that good health and reproduction can be maintained for a time when the sows are closely confined during the gestation period, but it is difficult. Under such restrictions it would be imperative that a complete, well-balanced, laxative ration be fed in carefully regulated amounts, and that special attention be given to the maintenance of sanitary conditions. Even with careful dieting and clean conditions, we should expect such inactivity to result finally in more frequent difficulty in farrowing, an increased tendency for the pigs to come weak, and a decrease in the number of strong pigs raised to the litter. And aside from the exercise feature, maximum range for pregnant sows is important in practice because of

the chance which it affords to cut down feed costs and the opportunity it offers the sows to obtain from the soil and vegetation the minerals and vitamins which are too often missing from the ration fed at the trough.

The problem of supplying exercise for the pregnant sows during the summer is solved naturally when they are maintained on pasture with a minimum of grain. The same is true with the other classes of hogs. In the case of the boar, his needs deserve particular attention, for confinement results in a sluggish disposition and a tendency to crampiness, both of which represent a serious handicap to his breeding performance later.

SANITATION

In the management of the breeding herd during the winter the condition of the sleeping quarters should be given attention. Pigs cannot thrive if the bed is damp. Rheumatism, colds, and pneumonia are the common results of overcrowded, dusty, and unsatisfactory housing conditions. The hog house should be warm without being close; it should not be drafty, but there should be enough ventilation to prevent steaming. The beds should be kept dry and the houses cleaned with sufficient frequency to keep them free from much dust.

The frequency with which the bedding should be changed and the quarters cleaned will depend chiefly on the weather and the character of the floors. When the weather is cold and things are frozen up tight, it is much easier to keep the quarters dry and sanitary than when the weather is warm and the ground soft. Likewise, well-constructed buildings with tight floors require much less work to keep clean than do poorly constructed houses with leaky roofs and dirt floors. As a rule, the houses should be cleaned thoroughly once a week. When the bedding has been removed, it is a good practice to lay the dust by sprinkling with crude oil. An occasional spraying with a strong disinfectant (4 percent coal-tar dip) is desirable. When the weather is cold, the bedding should be supplied in liberal quantities; when very warm, the less bedding used the better.

The houses and other sleeping quarters which are to be used by the hogs during the winter should be given a thorough going-over before cold weather sets in, having particularly in mind ridding the herd of any lice. This should consist of a thorough cleaning and disinfection of the houses and a careful systematic examination of the hogs for eggs and lice. Affected groups should be treated by spraying in close

pens or preferably by dipping, repeated once in a week or 10 days, using a 3 percent solution of a standard coal-tar dip, or liquor cresolis compound, plus crude oil sufficient for a ½-inch layer on top of the contents of the vat. A newer and most effective treatment consists of a single application of benzene hexachloride or chlorodane with a sprayer. It kills both lice and nits, and is equally effective against mange (see Chap. XXII). In connection with this clean-up campaign, it is essential to remove and burn or plow under all litter, straw that has been used for bedding, manure, corncobs, and the leavings of old straw stacks that may have been used previously as sleeping quarters by the hogs.

During the summer the herd is under conditions which are favorable for the maintenance of health and breeding thrift. With most of the farm fenced hog-tight, with adequate range, plenty of green feed, shade, and good water, the problems of management are practically solved. The cost of feeding and the work of handling also are reduced to a minimum when natural rather than artificial conditions prevail.

VII *Food Demands of the Growing and Fattening Pig*

Before considering the food demands of the pig it will be profitable to consider briefly some of the facts and principles relating to his growth and development, with the special object in mind of making it possible to understand better his food requirements at the different

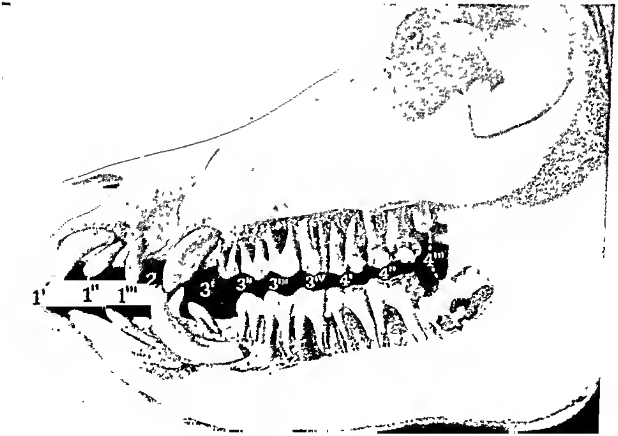


Fig. 30. Skull of pig about 1½ years old, sculptured to show the embedded parts of the teeth. 1^{I}, 1^{II}, 1^{III} incisors; 2, canines; 3^{I}, 3^{II}, 3^{III}, 3^{IV}, premolars, 4^{I}, 4^{II}, 4^{III}, molars. The third molar has not erupted and its roots are not yet formed *(from Sisson's* Anatomy of Domestic Animals. *Courtesy of W. B Saunders Company).*

stages of growth and to give information which will make us better judges of the results of feeding practices.

HOW THE PIG GROWS

The rate of development. As measured by the live weight, growth in the pig full-fed from birth takes place normally at an accelerating rate up to the weight of 200 to 250 pounds, and at a diminishing rate thereafter. From a study of the data supplied by 12 selected feeding experiments conducted at five Corn Belt stations, in all of which balanced rations were fed in the dry lot from soon after weaning to market weight, Atkinson and Klein of the Bureau of Agricultural Economics [1] found that the rate of gain reached a maximum (1.7 pounds daily) in the weight range of 200 to 210 pounds. By adjusting the weights from the different experiments to make them more comparable, and applying an appropriate mathematical formula to the data, the extended theoretical growth curve shown in Fig. 32 was obtained.

In Robison's experiments at the Ohio Station [2] 16 purebred Duroc Jersey pigs were full-fed individually in the dry lot from weaning to 400 pounds. With these pigs the maximum rate of gain occurred in the weight range of 200 to 300 pounds. The data of Ittner and Hughes of the California Station,[3] based on gains made by 457 pigs representing different groups but with a minimum of 150 pigs at each bi-weekly weighing, showed an acceleration in rate of gain up to the weight of 160 pounds only. These pigs were full-fed well-balanced rations, some with and some without pasture.

It should be clearly understood that these results, pictured graphically in Fig. 32, apply only to pigs that have been full-fed from birth. Pigs that have been grown on a limited ration and are in moderate condition when placed on full feed will make their maximum gains when at much heavier weights. A medium conditioned 300- or 400-pound hog when full-fed will gain more than 2 pounds daily while fattening. The type of hog will also affect the result. Those that fatten early during the growth period, as does the chuffy or small type, will reach their maximum gaining capacity at an earlier weight and age than will the large *later maturing types*.

When considered in relation to the size of the pig, the daily gains

[1] L. J. Atkinson and John W. Klein, U.S.D.A., Tech. Bul. 894, 1945.
[2] W. L. Robison, Bul. 335, 1919.
[3] N. R. Ittner and E. H. Hughes, *Jr. of Heredity*, Vol. 29, No. 10, 1938.

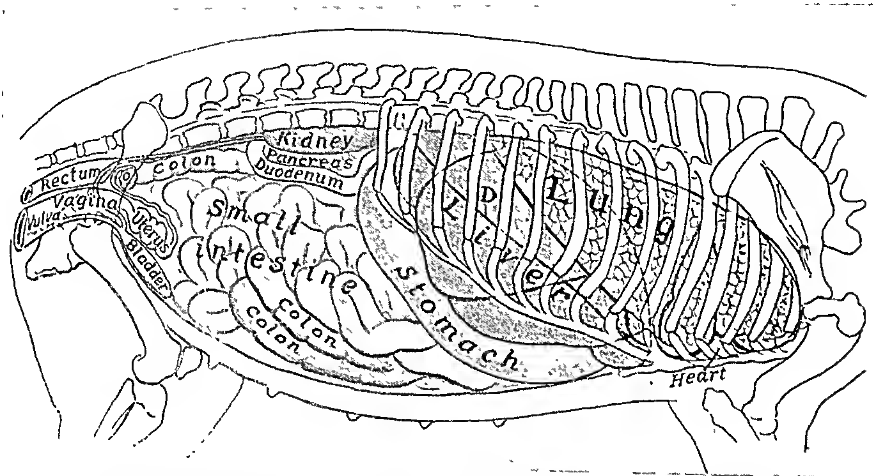
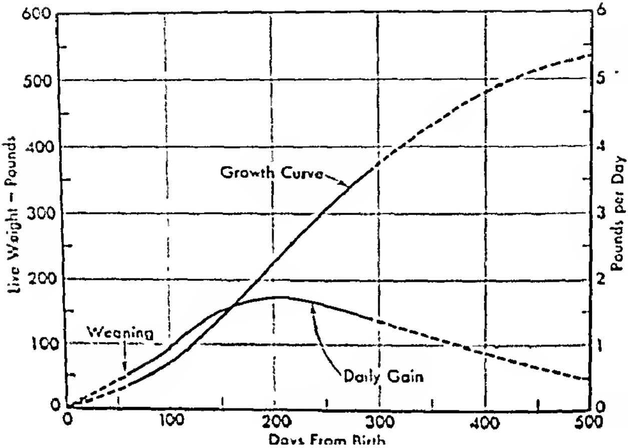


Fig. 31. Projection of viscera of pig on body-wall; right side. *D*, Costal line of diaphragm; *O*, ovary. The pancreas and duodenum are not in contact with the flank, as would naturally be inferred from this figure, but are situated more medially and are covered laterally by small intestine (*from Sisson's* Anatomy of the Domestic Animals, *courtesy of W. B. Saunders Co.*).


600
500
400
300
200
100
0
Live Weight – Pounds
6
5
4
3
2
1
0
Pounds per Day
Growth Curve
Weaning
Daily Gain
0
100
200
300
400
500
Days From Birth

weight and degree of finish which produces the weight and quality of cuts wanted by the consumer and is attained by good market pigs when they reach a live weight of 200 to 225 pounds. It is an interesting fact that, as the result of the development by breeding of the disposition to fatten early during the growth period, together with intensive feeding, this market finish is attained before the pig has completed one-half his growth cycle.

Pigs differ in their capacity for rapid gains. A fair average for healthy individuals full-fed good rations from birth up to the market weight of 225 pounds is 1 pound daily. With superior pigs and ideal conditions and rations, however, much faster gains are possible. Records made in the "ton-litter" extension projects of the various states show many instances of daily gains exceeding 1½ pounds from birth to five or six months of age, and of individual pigs which exceed 1¾ pounds a day. Such records are interesting because they show the possibilities attainable through the application of sound principles of breeding, sanitation, and feeding.

Why some pigs grow faster than others. The reason why some pigs make faster gains than others of the same weight and previous treatment when fed the same ration according to appetite has not been successfully explained. To say that some will gain faster than others because they are bred that way does not satisfy the question, although none can doubt that the ability is hereditary. Fast-gaining pigs probably are born with a larger appetite and a stronger growth impulse than slow-gaining pigs, which means a faster rate of cell division or growth. This implies a larger metabolic capacity for the retention and storing up of the elaborated food constituents and presumably also larger digestive and assimilating powers. Studies by Daugherty with the author [4] however, failed to show any significant agreement between the volume capacity of the digestive tract, or any of its parts, and the rate of gain made previously, although there was a rather close relationship between the gains and the length of the intestines when measured before emptying.

Gains as related to the capacity of the digestive organs. It will be of interest to note here the volume capacity and linear dimensions of the stomach, small and large intestines, in the studies just referred to. The figures, given in Table 38, represent averages for 12 pigs which had been on a feeding experiment where full rations were fed from soon after weaning and which weighed, when killed, an average of 250

[4] F. C. Daugherty, Purdue University, Master thesis, 1932.

pounds. They were well finished in condition at this time. The methods employed in making these measurements were such that the results are believed to be reliable for the number studied.

Table 38. Capacity and Linear Dimensions of the Digestive Organs of the 250-pound Pig

(Average 12 Pigs)

	Capacity	*Percentage Total Capacity*	*Length*
	qts.	%	ft.
Stomach	4.50	14.31	
Small intestines	14.30	46.41	58.50
Large intestines	12.10	39.28	16.16
Total	30.90 qts. or 7.72 gals.	100.00%	74.66 ft.

The length measurements given here for the small and large intestines correspond very closely with those given in earlier references. Laible of the Illinois Station [5] found the average length of the intestines of 58 pigs killed at a weight of 225 pounds to be 61 feet for the small and 15¾ feet for the large intestines. Stomach capacity, however, was found to be considerably less than that which has been reported in older references.

Although the 250 pound pig has a total capacity between seven and eight gallons, it is the smallest of any of the domestic animals. The pig has a capacity equivalent to 12 to 15 quarts for each 100 pounds live weight; for the horse it is approximately 19 quarts per hundredweight, and for cattle and sheep the capacity is approximately 30 quarts per hundredweight.

Daugherty's studies included also a determination of the capacity of the alimentary tract of pigs of varying ages. These data with some calculations are presented in Table 39. The seven pigs used in this study were crossbreds, litter-mates, and unusually vigorous and uniform. They had been full-fed from birth.

The number of pigs involved in this study is, of course, too limited to make valid any principles which might appear to be established respecting the relation of weight to the development of the digestive tract. The data do suggest, however, some interesting facts. Stomach capacity does not seem to increase with advancing age as markedly as does either that of the large or small intestines. The capacity of the

[5] R. J. Laible, Unpublished data, courtesy of W. E. Carroll, 1932.

Table 39. The Effect of Age on the Capacity of the Digestive Tract of the Pig

Weight of Pigs When Killed		*50 Lb. (av. 2 Pigs)*	*100 Lb. (av. 2 Pigs)*	*150 Lb. (av. 2 Pigs)*	*200 Lb. (1 Pig)*
Stomach capacity	Actual	1.62 qts.	2.80 qts.	3.65 qts.	3.92 qts.
	Per cwt.	3.24 qts.	2.80 qts.	2.43 qts.	1.96 qts.
Small intestines, capacity	Actual	5.14 qts.	8.17 qts.	16.44 qts.	15.68 qts.
	Per cwt.	10.28 qts.	8 17 qts.	10.96 qts.	7.84 qts.
Large intestines, capacity	Actual	2.30 qts.	5.40 qts.	9.19 qts.	9.96 qts.
	Per cwt.	4.60 qts.	5.40 qts.	6.13 qts.	4.98 qts.
Total capacity	Actual	9.06 qts.	16.37 qts.	29.28 qts.	29 56 qts.
	Per cwt.	18.12 qts.	16.37 qts.	19.52 qts.	14.68 qts.
Small intestines, length	Actual	50.00 ft.	50.92 ft.	54.75 ft.	55.25 ft.
	Per cwt.	100.00 ft.	50.92 ft.	36.50 ft.	27.62 ft.
Large intestines, length	Actual	8.58 ft.	10 08 ft.	12.75 ft.	14.00 ft.
	Per cwt.	17.16 ft.	10.08 ft.	8.50 ft.	7.00 ft.
Total intestinal length	Actual	58.58 ft.	61.00 ft.	67.50 ft.	69.25 ft.
	Per cwt.	117.16 ft.	61 00 ft.	45.00 ft.	34.62 ft.

large intestine increases at a rate equal to, if not exceeding, that of the growth weight. This is in marked contrast to the stomach capacity. With increasing growth, the capacity of the large intestines consequently represents an increasing proportion of the total capacity. The total capacity for each 100 pounds weight decreases only slightly with increasing weight. The amount of feed which a pig actually will consume for each 100 pounds weight is more closely related to the capacity of the stomach than to either the small or large intestines.

The small intestines are nearly as long in the 50-pound pig as they are in the 200-pound pig; the large intestines increase in length more perceptibly with advancing age. In neither case does the length increase in harmony with growth so closely as does the capacity. The increase which occurs in the actual capacity of the intestines with increased growth would seem to be, therefore, the result of change in diameter more than of length.

Gaining capacity as related to type. Many claim that the ability of a pig to make rapid gains on good rations is largely a question of type. The comprehensive studies of Carroll and associates of the Illinois Station,[6] covering a period of three years, 1922 to 1924, supply valuable information in this connection. Their results showed some superiority of the intermediate type over either the chuffy or rangy when hand-fed individually to a weight of 175 pounds. When self-fed by groups to a weight of 225 pounds, there was a significant difference in favor of the intermediate and rangy over the chuffy type. When self-fed

[6] W. E. Carroll, S. Bull, J. B. Rice, R. J. Laible, and R. A. Smith, Bul. 321, 1929.

on alfalfa pasture to a weight of 225 pounds, the intermediate outgained the rangy type by the difference between 1.76 and 1.68 pounds daily.

Results secured by Zeller of the U.S. Department of Agriculture [7] in general confirm these conclusions. In these studies pigs produced by breeding herds representing the small, intermediate, and large types were full fed well-balanced rations from weaning to approximate market weights. In one series of trials the three lots were fed to the same weight of 225 pounds, and in another series the tests terminated for each lot when it had reached desirable market finish. When fed to the same final or market weight, the average daily gain for each of the three types was as follows: small type, 0.90 pound; intermediate type, 1.08 pounds; and large type, 0.98 pound. There were 63, 172, and 196 pigs, respectively, in the three lots. In the other series, 85 small, 62 intermediate, and 94 large type pigs were fed to the same market finish, which was reached for the respective types at 143, 214, and 252 pounds. The average daily rate of gain of each lot in this plan was 0.86 pound for the small type, 1.26 pounds for the intermediate, and 1.24 pounds for the large type.

The importance of ancestry. The conclusion of the breeder, based on observation and experience, is that the size of the individuals represented in the parentage of the pig is a very important factor affecting his gaining ability. It is well to note here that large individuals are not necessarily of the rangy type, although this type usually grows to heavier weights than the intermediate or chuffy types. Weight records of the boars and sows which "placed" during the years of the National Swine Show indicate unmistakably that those breeds which were heaviest in the yearling and aged classes were heaviest also in the junior and senior pig classes.

Differences in ancestry or heredity also account for the fact that some strains and herds of the same breed and type are faster gainers than others. Pigs from the same litter, because of individual differences in hereditary endowment, differ in their capacity for growth. Inbreeding tends, in most lines, to result in some loss of growth vigor. Crosses between breeds, and between inbred lines, generally possess slightly more vigor and gaining capacity than the parental lines.

Environmental factors affect gains. Probably most of the differences in feed-lot performance, especially between herds, are not so much the result of differences in breeding as of differences in the environ-

[7] J. H. Zeller, *Proc. Am. Soc. An. Prod.*, 1940.

ment. The type of the ration fed, as it affects the nutrition and health of the pig, is obviously one of the most important of these factors. That disease and parasites are also responsible for large differences in the response of pigs to otherwise good conditions is appreciated by all experienced hogmen. Also, the housing and general environmental conditions, as they affect the comfort and general well-being of the pigs, are probably of more importance than is generally realized. The effect of extremes of temperature in reducing feed consumption and rate of gain has already been referred to (see page 134). The lack of convenience or quality in the water supply may, in fact, be responsible for unsatisfactory gains.

Table 40. Estimated Rate and Feed Cost of Gains and Feed Consumption, as Affected by the Weight of the Pig, Full-fed, Dry Lot

Weight of Pig	*Average Daily Gain During Period*	*Approximate Daily Feed Capacity per 100 Lb. Live Weight, During Period*	*Concentrates to Produce 1 Cwt. Gain During Period*	*Concentrates to Produce 1 Cwt. Gain, Cumulative from 30 Lb.*
lb.	lb.	lb.	lb.	lb.
30– 50	0.65	5 –5½	325	325
50–100	0.90	4 –4½	350	343
100–150	1.30	4	385	360
150–200	1.60	3½–4	420	376
200–250	1.75	3½	460	395
250–300	1.65	3	510	417
300–350	1.55	2½–3	585	443
350–400	1.40	2½	675	474
400–450	1.10	2	775	510
450–500	0.75	1½	925	554

The cost of gains increases with age. A second law observable in the development of the pig is that the amount of feed which is required to produce a unit of gain increases quite regularly from birth to maturity. This is a characteristic of all farm animals.

In Table 40 is given the amount of concentrates required to produce 100 pounds of gain in live weight at the different ages or weights under the average of good dry-lot conditions. These figures approximate in round numbers the data supplied by Atkinson and Klein. When on good forage, pigs will, on the average, make a unit of gain on 10 to 12 percent less concentrates than is required in the dry lot (see page 241).

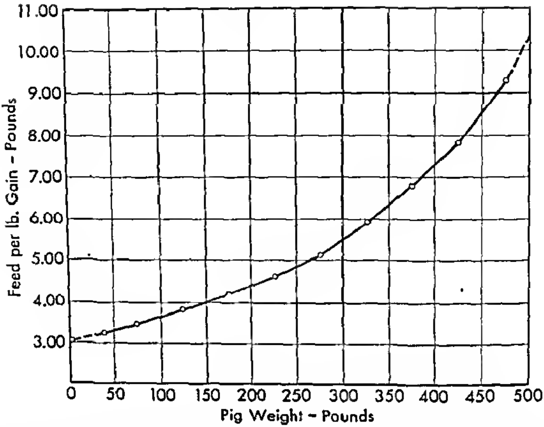


Fig. 33. Curve showing the approximate amount of concentrates required to produce a unit of live weight gain as the weight of the pig increases, full-fed from birth (see Table 40).

The determination of the feed cost for the period from birth to 50 pounds is intricate because of the varied nature of the pig's diet and the difficulty of determining his actual food consumption. Sufficient data are available, however, to indicate that the feed cost at that period is much lower than at any subsequent period. Evvard's studies with orphan pigs at the Iowa Station [8] furnish information covering most of this period. He hand-fed two groups of pigs, 16 in one and 7 in the other, from an average beginning weight of 8.6 pounds to a final weight of 34.5 pounds for one group and to 56.8 pounds for the other. The weighted average amount of feed in terms of concentrates required to produce 100 pounds of gain was 183.6 pounds. Thirty-two percent of the solids consumed, on the average, was from cow's milk. Beach of the Connecticut Storrs Station [9] hand-fed two pigs on low-fat cow's milk for a period of 40 days, and four pigs for a period of 30 days, beginning immediately or soon after birth. He found that it required an average of 138 pounds of milk solids to produce 100 pounds of gain.

Olofsson and Larsson of the Svalov Experiment Station, Sweden,[10]

[8] John M. Evvard, Res. Bul. 79, 1923.
[9] C. L. Beach, Bul. 31, 1904.
[10] N. E. Olofsson and Larsson, *Abst.*, E.S.R., Vol. 67, No. 1, 1932.

estimated from studies made of the milk production of 200 sows covering 6 to 8 weeks of the nursing period that the pigs made a gain of 1 pound in live weight on the equivalent of 1.09 feed units or pounds of concentrates. In thesis studies by Blaydes and Husted,[11] under the direction of the author, two litters of pigs during the period from the age of 2½ to 24½ days gained at the rate of 100 pounds for each 55.6 pounds of solids in the mother's milk. The consumption of milk was determined in three separate 24 test periods by keeping the sows and litters separate and weighing the individual pigs immediately before and after each of the eight nursings allowed during each period.

Why young pigs gain economically. The fundamental reason for the greater gain in live weight by the young as compared with the old pig from a given unit of feed is to be found chiefly in the character or nature of the gains. The animal body is made up of water, ash, protein, and fat. As the pig grows and fattens, the proportion of these constituents changes considerably, especially the fat and water. The amount of water in the tissues of the animal decreases from birth to maturity and the percentage of fat increases; the proportion of the ash and protein decreases slightly. This is shown by the figures given in Table 41, representing the average chemical analysis of the entire empty weight of pigs at different stages of development.

Table 41. Chemical Composition of Pigs, Empty Live Weight

Age or Weight	*Number of Pigs*	*Water*	*Fat*	*Protein*	*Ash*	*Station*
		%	%	%	%	
New-born	3	80.46	2.08	15.25	4.00	Mo. Exp. Sta.[a]
55 days	5	70.67	9.74	16.56	3.06	Wellman[b]
100 lb.	60	66.76	16.16	14.94	3.12	Mo. Exp. Sta.[c]
150 lb.	6	56.07	29.08	14.03	2.83	Mo. Exp. Sta.
200 lb.	12	53.99	28.54	14.48	2.66	Mo. Exp. Sta.
250 lb.	40	51.28	32.14	13.37	2.75	Mo. Exp. Sta.
300 lb.	10	42.48	42.64	11.63	2.06	Mo. Exp. Sta.

[a] H. P. Armsby and C. Robt. Moulton, *The Animal as a Converter of Matter and Energy*, The Chemical Catalog Company, Inc., New York, p. 51, 1925.
[b] *Ibid.*, p. 56.
[c] A. L. Hogan, L. A. Weaver, A. T. Edinger, and E. A. Trowbridge, Res. Bul. 73, 1925.

Analysis of the empty weight of 58 pigs ranging in weight from 55 to 275 pounds by Mitchell and Hamilton [12] gives figures quite comparable to those in the above table. These authors emphasize the fact that the dominating factor in the changes which occur in composition

[11] H. S. Blaydes and G. H. Husted, Purdue University, 1931.
[12] H. H. Mitchell and T. S. Hamilton, Ill. Exp. Sta., Bul. 323, 1929

with advancing age is the percentage of fat. They make the important observation that, on a fat-free basis, there is remarkably little change, particularly after the pig reaches the weight of 150 to 175 pounds. Their figures for this period, characteristic of the mature animal, are 75 to 76 per cent of water, 20 to 21 per cent of crude protein, and 4 per cent of ash.

At birth the pig is about 80 percent water and 2½ percent fat; at a weight of 300 pounds he is 42 percent water and 42 percent fat. It is obvious, therefore, that the gains made by the young pig, composed as they are more largely of water and less of fat, would require less food for their production than would the same amount of increase later in life when they are composed more largely of fat and less of water.

Another reason accounting for greater economy of gains by young pigs is to be found in his larger feed consumption. As he advances in age and weight his consumption of feed according to weight diminishes, as indicated by the figures in Table 40. As a result of this larger food consumption by the younger pig, there is left, after maintenance requirements have been satisfied, a larger proportion of the ration available for increase in weight, which means larger gains from the same unit of feed. The young pig may digest his rations a little more completely than the older pig, but the two principal factors responsible for the greater economy of his gains are those resulting from the nature or composition of the gains themselves and his larger feed capacity.

The amount fed influences economy of gains. The amount of the ration fed is a factor affecting the amount of live weight gain made from a unit of the feed. When the quantity fed is so limited that the maintenance needs only are met, its efficiency measured in terms of gains is zero. As the amount fed is increased beyond maintenance requirements, its so-called efficiency increases. Theoretically, one would expect this efficiency to increase regularly with each increment of feed until a full ration is fed, since the maintenance needs remain nearly constant and the total maintenance requirement decreases as a result of the shorter feeding period. Actually, however, the gains made from a unit of feed increase only up to the point where a two-thirds to three-fourths full ration is fed. From this point up to the full capacity of the pig his efficiency decreases slightly.[13]

[13] N. R. Ellis and J. H. Zeller, "Effect of Quantity and Kinds of Feed on Economy of Gains and Body Composition of Hogs," Tech. Bul. 413, U.S.D.A., 1934; J. M. Saint-Pierre, F. B. Morrison, and J. P. Willman, "Relative Efficiency of Limited and Full-Feeding for Fattening Pigs in Dry Lot," *Am. Soc. An. Prod., An. Rep.*, 1934.

There are two principal reasons which explain this decrease in apparent economy of gains. The first is that the full ration is not quite so completely digested as the limited one, and second, the composition of the gains made on the full ration, made up as they are more largely of fat and less of growth products and water, is more concentrated in character and hence more expensive. Even when fed to the same market weight, pigs receiving a limited ration grow more and fatten less than do those fed a full ration.

Feed costs measured in edible food products. It should be emphasized here that the feed cost of gains up to the various weights, as shown in Table 40, does not represent the entire feed cost, since the cost of maintaining the breeding herd was excluded. The figures consequently represent only a part, although the larger, of the total feed cost of producing the finished market pig.

Also, it is important to note that, from the standpoint of human food production, the feed cost per unit of dressed carcass or of edible food increases much less rapidly with advancing weights than when measured in terms of live weight gains.[14] The economic importance of these facts is considered further in Chapter XVI.

FOOD DEMANDS OF THE GROWING AND FATTENING PIG

The unrestricted activity of the wild ancestor of our present domesticated hog enabled him to gain subsistence from the mast, herbs, succulent bulbs, larvae, grass, and earthy materials of the forest and fields. His food demands were the same, in kind, as are those of the modern hog; but his size was smaller, his rate of gain slower, and his capacity to reproduce young more limited. The primitive hog was fitted by nature to his environment and probably rarely suffered from disease or ailments which were the result of imperfect nutrition.

The modern hog, on the other hand, has been marvelously improved by selective breeding in the capacity for growth and reproduction. At the same time his range has been limited and his opportunity to obtain variety in his diet has been greatly restricted. As a result of the larger food demands thus created and the artificial conditions generally imposed on his mode of life, it probably is the exception rather than the rule when the modern hog does not suffer some form of nutritional disturbance at some time during his life. The animal's dependence on man and the wide variety of food substances required for his nourishment have made it imperative for the present-day feeder to have a

[14] L. J. Atkinson and John W. Klein, U.S.D.A. Tech. Bul. 917, 1946.

fairly clear understanding of his nutritional needs and of practical methods of meeting them.

The food requirements of the growing and fattening pig may be enumerated briefly by grouping them in the following general classes: (a) energy and heat, (b) protein, (c) minerals, and (d) vitamins.

Energy and heat. What might be called the first food demand of any animal is for substances which will furnish energy to run the body machine and heat to supply it with warmth. These requirements are met principally by the carbohydrates (starches) and fats of the ration, although the digested proteins ultimately yield about two-thirds of their energy. If more of these nutrients are given than are necessary to supply the needed body energy, they may be stored up as body fat. It is the richness of corn in carbohydrates or starches that makes it the supreme energy-furnishing or fattening feed. The demand for energy is the largest, quantitatively, of any of the food requirements, but as a result of the abundant supply of carbohydrates in all the cereal grains it is exceptional when the average home-grown ration, especially in the Corn Belt, does not supply an excess in proportion to the other classes of food material.

Maintenance requirements. A considerable proportion of the ration fed to the growing and fattening pig is required for maintenance; only that part which is supplied beyond this need is available for gains. Extensive chemical studies by Mitchell and Hamilton of the Illinois Station[15] have furnished the facts which confirm the old rule that approximately 1 pound of feed daily per 100 pounds live weight is required to maintain the pig at a constant weight. Mitchell and Hamilton determined that this rule applied equally well to young pigs weighing from 50 to 70 pounds and to fat pigs weighing 225 pounds, and pointed out, however, that when young pigs are fed a ration which keeps them at a constant weight, they are not in a state of real maintenance or equilibrium. The growth impulse is so strong in the young animal that with so-called maintenance or submaintenance rations the pig continues to grow in height and to shrink in thickness. In this situation he gains in body protein, ash, and water, and loses an equivalent weight of body fat. To maintain energy equilibrium these authors determined that the young pig weighing 50 to 70 pounds requires about 1.50 pounds of feed daily per 100 pounds live weight, while for older pigs weighing 225 pounds or more the requirement is 0.95 to 1.13 pounds.

[15] H. H. Mitchell and T. S. Hamilton, Bul. 323, 1929.

The energy required for maintenance increases as the temperature is lowered below a certain point, called the critical temperature. Wood [16] has estimated that this is about 20°C, or 68°F, for the pig fed a maintenance ration, and 43°F when fed a normal growing ration. Below this critical point a lowering of the temperature will mean an increase in the oxidations required to sustain the body temperature at normal. The economy with which the growing and fattening pig uses his food will consequently not be affected by the weather, except as it may influence feed consumption, unless the temperature of the pig's environment falls below this point. It is important also to know that those classes of hogs fed but little more than maintenance rations naturally will suffer sooner from cold than those fed heavier rations.

Certain fat compounds are essential. Although the energy needs of the pig can be satisfied by carbohydrates alone, these needs are more efficiently met by supplying some fat along with the carbohydrates. Fats are 2¼ times richer in energy than carbohydrates, but the increased efficiency resulting from a combination of the two appears to be greater than can be accounted for by the more concentrated energy supply.[17] Fat is important in the ration also because it serves as a carrier of the fat-soluble vitamins.

In two experiments at the Indiana Station, Witz and Beeson [18] studied the physiological effects of a low-fat diet on the pig. One pig of each of the four pairs in each experiment was hand-fed a practically fat-free synthetic diet (in Experiment I it contained 0.12 percent of ether extractable material, and in Experiment II 0.06 percent), while their litter-mate pairs were fed the same diet with 5 per cent of lard added. The trials began soon after the pigs were weaned and continued for periods of 56 and 77 days, respectively.

On both the practically fat-free diets the authors reported the development of the following external fat-deficiency symptoms: "A scaley dandruff-like dermatitis on the tail, back and shoulders; loss of hair; a brown gummy exudate on the belly and sides; necrotic areas on the skin around the neck and shoulders; and an unthrifty appearance. The addition of 1.5 percent of corn oil to the diet of the pigs receiving the low-fat rations caused some recovery from these symptoms in three weeks of treatment."

[16] T. B. Wood, *Animal Nutrition*, 2nd ed., University Tutorial Press, Ltd., London, 1927.

[17] Leonard A. Maynard, *Animal Nutrition*, 2nd ed., McGraw-Hill Book Company, Inc., New York, 1947, p. 78.

[18] W. M. Witz and W. M. Beeson, Journal Paper No 464, 1950.

Fig. 34. Showing the effects of a low-fat (0.06 percent ether extract) diet. Note loss of hair, scaly dandruff, especially on feet and tail *(courtesy, Dr. W. M. Beeson, Ind. Exp. Sta.; photo by Allen).*

The pigs restricted to the practically fat-free diet in Experiment II (0.06 percent ether extract) made highly significantly slower gains than those fed the ration conntaining 5 percent of fat. The addition of 1.5 percent of corn oil to the fat-free diet resulted in an immediate increase in growth rate. In Experiment I, the pigs which received the practically fat-free diet containing 0.12 percent of either extract made practically as rapid gains as their paired litter-mates on the diet containing 5 percent of fat. In neither experiment was the feed consumption greatly affected by the amount of fat in the diet.

The pigs which received practically no fat in their diet had underdeveloped digestive organs and small gall bladders. Sexual maturity was retarded in the case of the pigs receiving the fat-free diet in Experiment II.

According to Maynard's review of the literature the special importance of fat in the diet is to be attributed to the unsaturated fatty acids, linoleic, linolenic, and arachidonic, which are found in feeds along with the other fats. Judging by the effects of their absence on laboratory animals and the recent experiments of Witz and Beeson, they should be regarded as necessary in the ration of the pig. Since

these unsaturated fatty acids cannot be synthesized in the animal body from the carbohydrates or saturated fats, they merit the designation of essential fatty acids.

The ordinary ration with a fat content of 2 percent or more probably supplies these essential fats in abundance. Most animal fats and the oil of the soybean, cottonseed, and peanut are reported to be especially rich in them.

Protein requirements. The animal also requires a constant supply of protein or nitrogenous material to meet his daily needs. Food protein is necessary for the growth of muscle and other protein tissues, such as the vital organs and the bones, and for their repair. None of the other food constituents can perform this function. To meet the needs of the growing and fattening pig one part of protein is required in the ration to five to eight parts of carbohydrates or equivalent. The younger the pig the greater are his demands for protein; with advancing age the demands for fat production, supplied mainly by the carbohydrates of the ration, assume increasing importance. Since the cereal grains are deficient in protein, resort must be made to specially grown crops or to the purchase of protein supplements on the market in order to have rations that are balanced in these two classes of food constituents.

A fact of considerable practical importance that should be noted here is that the protein supply must be continuous. Unlike some of the other food constituents, such as the minerals and most of the vitamins, protein cannot be stored up as a body reserve to be available later to supplement a deficient supply in the ration.

Recommended protein allowances. A fairly liberal supply of protein must be fed if the pigs are to remain thrifty, make efficient use of their rations, and gain rapidly. The amount required at the various stages of development has been the subject of numerous and extensive experimental studies. Unfortunately, however, because of differences in the quality of the proteins fed, a lack of knowledge concerning its digestibility in different feeds and combinations, and as a result of the conflicting effects of vitamins and other unknown food factors at the time, the results have been such that exact amounts, in terms either of digestible or crude protein, cannot be stated. For all practical purposes, however, the recommended allowances, as given in Table 42, are believed to approximate the actual requirements sufficiently closely to make them valuable as general guides.

Table 42. Recommended Protein Allowances for Growing and Fattening Pigs

Weight of Pig	*30–50 lb.*	*50–100 lb.*	*100–150 lb.*	*150–200 lb.*	*200–250 lb.*	*250–300 lb.*
Percentage Crude Protein, in Dry Lot	21–19	18–16	15–14	14–13	13–12	12–10
Percentage Crude Protein, on Good Legume Forage	18–16	15–13	13–11	11–10	10– 9	9
Percentage Crude Protein, on Non-legume Forage	20–18	17–15	15–13	13–11	11–10	10

The figures represent percentages of the air-dry ration. In arriving at these estimates, which are in fact compromises, consideration was given especially to Morrison's recommendations,[19] the results of studies by Keith, Miller, and McCarty of the Pennsylvania Station,[20] and to the allowances suggested in the report of a committee of the National Research Council.[21]

Since feeds which are high in their protein content are scarce and expensive compared with corn and other cereals, as in the Corn Belt, rations containing less than the recommended amounts will often be more economical. For most efficient production, however, it rarely would be advisable to feed less than the minimums suggested. In practice the proportion of protein concentrates should be modified at least twice, unless the supplement is fed free-choice, namely, when the pigs reach the weight of about 75 pounds and again at a weight of about 150 pounds.

Protein content of common feeds. It will be informing to observe at this time the amounts of protein compared to the carbohydrates and fats contained in the different classes of common swine feeds, as shown in Table 43.

Corn and other cereals, it is to be noted by the table, are as a class very low in their content of protein. This, with their high content of carbohydrates and fats, gives them rather wide nutritive ratios. Corn especially is overabundantly supplied with the fattening constituents

[19] F. B. Morrison, *Feeds and Feeding*, 21st ed., The Morrison Publishing Co., Ithaca, N. Y. Appendix, Table III, 1948.

[20] T. B. Keith, R. C. Miller, and M. A. McCarty, Bul. 401 and 407, 1940 and 1941.

[21] Prepared by E. H. Hughes, E. W. Crampton, N. R. Ellis, and W. M. Beeson, 1950.

Table 43. The Protein Content of Swine Feeds [22]

Feeds	*Moisture*	*Crude Protein*	*Carbohydrates: Nitrogen-free Extract*	*Carbohydrates: Crude Fiber*	*Fats*	*Nutritive Ratio* [a]
	%	%	%	%	%	1:
Cereal grains:						
Corn, No. 2	15.0	8.6	69.3	2.0	3.9	11.1
Wheat	10.5	13.2	69.9	2.6	1.9	6.2
Barley	10.2	8.7	70.9	5.7	1.9	10.4
Oats	9.8	12.0	58.6	11.0	4.6	6.5
Rye	10.5	12.6	70.9	2.4	1.7	6.6
Kafir	10.2	10.9	72.7	1.7	2.9	8.3
Plant supplements:						
S. wheat *middlings*	10.4	18.1	55.8	6.5	4.8	4.1
Flour middlings	10.8	18.3	59.8	3.8	4.2	3.9
Wheat bran	9.9	16.9	52.9	9.6	4.6	3.9
Soybeans	10.0	37.9	24.5	5.0	18.0	1.6
Soybean oil meal	8.8	44.6	29.4	5.8	5.3	1.1
Linseed oil meal	9.0	35.0	36.4	8.3	5.7	1.5
Cottonseed meal	7.3	43.9	26.3	9.0	7.1	1.1
Animal supplements:						
Whole cow's milk	87.2	3.5	4.9	0.0	3.7	3.9
Skimmilk	90.5	3.6	5.1	0.0	0.1	1.6
Buttermilk	90.6	3.5	4.5	0.0	0.6	1.8
Whey (skimmed)	93.4	0.9	5.0	0.0	0.0	6.4
Condensed buttermilk	70.3	10.9	12.6	0.0	2.2	1.7
Tankage or meat meal	6.9	60.6	1.8	2.0	8.5	0.3
Meat scraps	6.2	60.9	1.1	2.4	8.8	0.4
Meat and bone scraps	6.1	51.0	1.6	2.1	10.1	0.5
Fishmeal, menhaden	6.4	62.2	4.2	0.7	8.5	0.4
Bloodmeal	8.2	84.5	0.7	1.0	1.1	0.02
Legumes:						
Alfalfa hay	9.5	14.8	36.6	28.9	2.0	3.8
Alfalfa hay, very leafy	9.5	17.2	39.4	22.6	2.6	3.2
Alfalfa leaf meal	7.7	21.2	39.7	16.6	2.8	2.5
Red clover hay	11.9	11.8	40.1	27.2	2.6	6.4
Ladino clover hay	12.0	19.4	34.9	20.7	3.2	2.9
Soybean hay	12.0	14.4	35.8	27.5	3.3	4.1
Soybean straw	11.2	4.0	37.5	41.1	1.1	31.1
Cowpea hay	9.6	18.6	34.6	23.3	2.6	3.2
Alfalfa forage, before bloom	80.2	4.1	8.3	4.6	0.7	2.8
Red clover, before bloom	81.3	4.3	9.2	2.6	0.6	3.2
Ladino clover, forage	83.7	4.4	7.1	2.2	0.4	2.1

[a] The nutritive ratio is the ratio of the digestible protein, taken as unity, to the digestible nonprotein organic nutrients. The latter is called the carbohydrate equivalent and is obtained by multiplying the digestible fat by 2.25 and adding the product to the digestible carbohydrates. Owing to the limited information concerning the digestibility of feeds by swine, it is the more common practice now to express the protein content as a percentage of the air-dry feed or ration.

[22] F. B. Morrison, *Feeds and Feeding*, 21st ed., Appendix, Table I, 1948.

(carbohydrates and fats) and underprovided with the growth-promoting materials (protein). At no stage in the pig's development can his demand for protein be satisfied by corn alone.

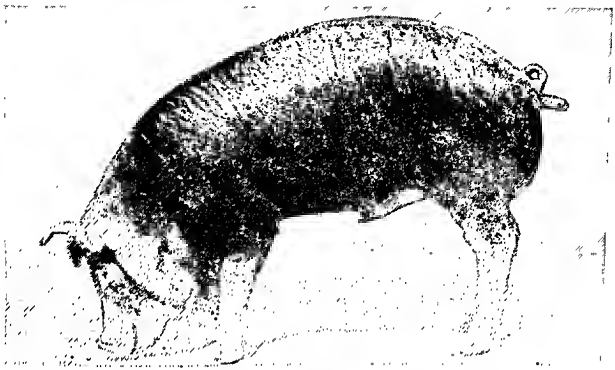
Compared with the cereal grains, the commercial feeds, grouped in the table as plant and animal supplements, are relatively high in their content of protein. So also are the legumes. One of the principal reasons why a supplement must be fed along with corn or other cereal to growing and fattening pigs is because without it the protein needs would be unsatisfied and growth stunted.

The legumes as a class are richer in protein than the grains. Although the digestive capacity of the pig is too limited to make it possible for him to consume any considerable amount of these feeds either as green forage or hay, the small amount of dry matter which he can take in this form may contribute materially to the protein supply. Especially is this true when a limited grain ration is fed on forage. When running on good legume forage, the protein needs of the pig will be satisfied by feeding in the dry ration from three-fourths to two-thirds the amount which would be advisable under dry-lot conditions (see page 164).

Quality of the protein is important. It should be emphasized at this point that in order to be efficient the protein supply must be of a certain kind or quality. The protein tissues of the growing pig are made up of various combinations of 20 or more separate nitrogen-containing constituents called amino acids. These amino acids are the "building-stones" with which the animal constructs the tissues of growth. Each tissue has a special architecture, as it were, and requires these building stones in certain definite proportions. In the process of digestion the proteins of the ration are broken down into their amino acid constituents and are absorbed and transported to the growing cells as such. If the protein supplied contains all of these amino acids in the variety and proportions needed for growth or replacement purposes, it may be regarded as superior in quality, or complete, while, on the other hand, if certain of the amino acids are limited or entirely missing, it is inferior in quality.

The proteins of milk, meat, and eggs are more efficient than are those of the cereal grains because of differences in their amino acid make-up. Although the animal is known to be capable of constructing some of these amino acids from the general protein supply and hence is not dependent on the feed to provide them ready-made, it is known, on the other hand, that certain other amino acids cannot be synthe-

sized. These are the so-called essential amino acids. Judging from the requirements of similar species, the number of these in the case of growing pigs is probably 10, although experimental evidence is lacking



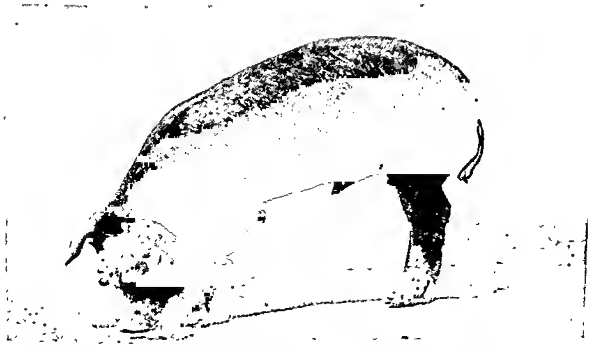


Fig. 35. The amino acid lysine is essential in the diet of the pig *(courtesy, Dr. W. M. Beeson, Ind. Agr. Exp. Sta.).*

Upper: This pig, fed 2 percent D.L.-lysine. HCL. plus the lysine-deficient ration, gained 25 pounds in 28 days.

Lower: This pig, fed the lysine-deficient ration alone, lost 2 pounds in 28 days.

for all excepting two, tryptophane and lysine. Recently these have been shown to be indispensable in the diet of the pig by Beeson and associates of the Indiana Station.[23]

What is most significant is the fact that the amino acids known to be indispensable in the feed supply are the particular ones which are found in most meager amounts in the cereal grains. It is possible that one of the reasons why skim milk and tankage are more efficient as balancers of corn than are the plant supplements like linseed oil meal and shorts is because their proteins carry a large proportion of these particular amino acids. These facts are of considerable importance to the practical feeder because they suggest the need of discrimination in the selection of protein feeds and the possibility of securing even greater biologic efficiency by feeding a combination of two or more feeds than can be obtained by one. It is important to note here the fact that all the essential amino acids must be present in the body simultaneously before synthesis or growth can occur.[24]

Animal and plant supplements compared. Protein supplements of animal origin are more efficient for balancing corn and the other cereals than are those of plant origin, but much, perhaps most, of the difference in efficiency is due to other factors than the quality of the proteins. Animal supplements, such as tankage, fish meal, and the milk products contain large supplies of minerals, especially calcium, and certain important vitamins belonging to the B-complex group, which the plant supplements lack. Mitchell of the Illinois Station [25] says that no general statement can be made concerning the proportions of the essential amino acids that will sharply distinguish one group of proteins from the other. However, he recommends that when plant protein feeds are substituted for animal protein feeds, the protein content of the ration be raised one-fourth to allow for less efficient utilization, even when adequate supplies of minerals and vitamins are provided.

Mineral demands. At least 13 mineral elements are known to be essential to animal life. These are sodium, potassium, calcium, magnesium, manganese, iron, copper, cobalt, zinc, phosphorus, chlorine, iodine, and fluorine. Although they are required in rather minute amounts, compared with the proteins and carbohydrates, they constitute nevertheless an indispensable part of every complete ration.

[23] W. M. Beeson, E. T. Mertz, and D. C. Shelton, *Science*, Vol. 107, p. 599, 1948; E. T. Mertz, D. C. Shelton, and W. M. Beeson, *Jr. An. Sci.*, Vol. 8, No. 4, 1949.

[24] E. Geiger, *Jr. of Nut.*, Vol. 36, No. 6, Dec., 1948.

[25] H. H. Mitchell, National Research Council, Reprint and Circular Series No. 117, May, 1943.

That part of a feed stuff which is left after complete burning, the ash, contains most of these minerals. They are essential components of all the secretions, liquids, and tissues of the animal body, and are necessary for the support of all the vital processes. Their most obvious use is for the growth of the skeleton or bony framework. About 78 percent of all the ash or mineral matter of the animal body is found in the bones and these are composed mainly of calcium and phosphorus.[26]

An adequate daily supply of minerals is needed by the pig in the interests of health and thrift. If for any reason there is a deficiency in the supply of any one of them for a period long enough for the body reserves to become exhausted, serious nutritional disturbances progressively expressed in a lack of thrift, depraved appetite, scurfy skin, stiffness, muscular incoordination, rachitis, posterior paralysis, and death, may result. Anemia and goiter (hairlessness) are diseases in the young pig known to be the result respectively of iron and iodine deficiencies. Fortunately, most of the mineral elements are supplied in adequate amounts by good rations. In the case of common salt and calcium, however, the supply is often insufficient, especially when range is limited and cereal grains and their by-products constitute the ration. Under special conditions, the supply of phosphorus, iron, and iodine also are limiting factors.

Trace minerals. The need for the so-called trace mineral elements, such as iron, copper, cobalt, zinc, magnesium, manganese, and sulphur, as contained in most commercial mineral mixtures, beyond the quantity normally supplied in good rations and a simple mineral mixture, is doubtful. On the basis of experimental evidence, there would appear to be no justification for their use except in specialized areas where, because of peculiar or depleted soil conditions, the need for one or more of them has been demonstrated. The quantitative requirements of the pig for these several trace elements have not yet been determined.

Fluorine deserves some attention in swine feeding because large doses are poisonous. The only situation, however, where there is any likelihood of an oversupply is when rock phosphate is used as a carrier of calcium and phosphorus in the mineral mixture. A regulation of the American Feed Control Officials states that the fluorine content of a mineral or mineral mixture for swine shall not exceed 0.45 percent.

[26] Laws and Gilbert data in Armsby's *Nutrition of Farm Animals.* The Macmillan Co., New York, 1917, p. 62.

Mineral feeding standards. It is not known precisely just what quantity of each of the several minerals is required for the growing pig. There are several reasons why a statement of exact standards is difficult, if not impossible. In the case of calcium, for example, the amount which is satisfactory for a moderate rate of growth might not be adequate when growth is pushed at a maximum rate by the full feeding of protein-rich rations. Again, the efficiency with which a given supply is used, or the proportion retained in the body, is influenced considerably by the age of the pig, the amount of sunshine in his environment, the supply of vitamin D, the calcium-phosphorus ratio, and possibly also by the amount and proportion of certain other mineral elements in the ration.

Another fact which makes difficult an accurate determination of the critical lower limits in the supply is that the large amount of mineral reserves contained in the bones enables the pig to survive a considerable period of mineral-deficient feeding, especially of calcium, without showing any symptoms of malnutrition. The phosphorus of the skeleton, however, unlike the calcium, is not readily available for relief during a period of phosphorus-deficient feeding. What is true of calcium is true also of most of the other mineral elements, although probably to a lesser extent. The difficulty of suiting the ration to the mineral needs of the pig is further complicated by a lack of full information concerning the mineral content of feeds and the variations which result from differences in fertility and water content of the soils which produced them.

The mineral requirements of the growing and fattening pig have been extensively investigated by many scientists and research institutions here and abroad. These studies, together with the practical feeding tests which have been carried out by the experiment stations, have provided the basis for the recommendations made below for the three minerals of greatest economic importance. The percentages are of the air-dry feed or ration.

Calcium (Ca)	0.30 to 0.60 percent
Phosphorus (P)	0.25 to 0.50 "
Common salt (NaCl)	0.25 to 0.40 "

The above estimates are sufficiently broad, it is believed, to ensure a reasonable margin of safety when the supply of vitamin D and sunshine is adequate. The larger amounts are recommended for young pigs, and the smaller for those more mature. Since the calcium require-

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The mineral content of feeds. The mineral elements most likely to be found in insufficient amounts in rations for pigs are calcium, phosphorus, sodium, and chlorine. The percentages of these in the common swine feeds are shown in Table 44. Most of these figures are taken from Bulletin 99 of the National Research Council, 1937, prepared by H. H. Mitchell and F. J. McClure; those indicated with asterisks are from Indiana Experiment Station Circular 351, April, 1949.

A general inspection of the figures shown in Table 44 will reveal some important facts. In the case of the cereal grains it is to be noted that they all are extremely low in all these mineral elements, particularly in calcium and salt. Although also low in phosphorus, they contain from 3 to 25 times as much of this element as of calcium. The protein supplements of plant origin also are to be regarded as seriously deficient in calcium and salt but relatively rich in phosphorus. On the other hand, the meat and fish by-products, caused principally by their high bone content, are abundantly supplied with both calcium and phosphorus. Also, the salt content of these feeds is considerably higher than in the cereals or their products. Skim milk and also buttermilk are fairly high in all these minerals, and with a well-balanced ratio between the calcium and phosphorus.

In marked contrast with the cereals and their products, the legume hays are especially rich in calcium while being relatively low in phosphorus. Green forages are known to be even richer in these elements, on the dry-matter basis, than the hays. The figures showing the calcium and phosphorus content of the common mineral sources will be useful in calculating the content of these elements in rations and simple mineral mixtures. The simple mineral mixture of two parts steamed bone meal, two parts limestone dust, and one part common salt contains approximately 27.4 percent of calcium, 5.4 percent of phosphorus, and 20 percent of salt.

The need for a mineral supplement when any of the cereal grains is balanced with a protein supplement of plant origin is obvious. But

[27] H. H. Mitchell, *Jr. An. Sci.*, Vol. 6, No. 4, Nov., 1947.

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[27] H. H. Mitchell, J. An. Sci., Vol. 6, No. 4, Nov., 1947

Table 44. Essential Minerals in Common Swine Feeds

Feed	Minerals on Dry-matter Basis				
	Ash	*Calcium*	*Phosphorus*	*Sodium*	*Chlorine*
	%	%	%	%	%
Cereal grains:					
Corn	1.23	0.01	0.29	0.02	0.04
Wheat	1.64	0.06	0.42	0.03	0.09
Oats	2.70	0.12	0.41	0.13	0.14
Barley	2.39	0.07	0.41	0.08	0.17
Plant supplements:					
Linseed meal	5.82	0.39	0.92	0.10	0.44
Soybean oil meal	5.79	0.27	0.68	...	...
Cottonseed meal	6.02	0.21	1.20	0.05	0.03
Corn gluten feed	4.55	0.11	0.85	1.03	0.22
Wheat middlings	3.86	0.10	1.00	0.11	0.04
Red dog flour	2.16	0.05	0.57	...	...
Wheat bran	5.06	0.10	1.26	0.04	0.04
Rice polish	7.13	0.03	1.68	0.12	0.15
Animal supplements:					
Meat meal	15.4	3.30	1.79	1.83	2.69
Fishmeal, white	17.6	6.64	3.46	1.58	1.65
Tankage, 60% protein	22.1	7.60	3.99	...	...
Tankage, 50% protein	28.3	11.70	5.15	...	...
Blood flour	3.04	0.44	0.24	0.42	0.32
Cow's milk	0.76	0.90	0.77	0.52	0.86
Skim milk	0.69	1.33	0.98	0.49	0.95
Legume hays:					
Alfalfa	7.70	1.63	0.22	0.10	0.22
Alfalfa leaves	13.60	3.77	0.29	0.11	0.54
Red clover	6.72	1.09	0.14	0.03	0.05
Soybean	7.67	1.38	0.24	0.14	0.08
Vetch	6.17	0.80	0.25	...	...
Minerals:					
Raw bone meal	63.30	24.10	11.40	0.55	0.04
Steamed bone meal	83.60	31.00	14.40	0.48	0.06
Bone black *	...	23.00	11.50	...	...
Defluorinated phosphate *	...	24.00	13.00	...	...
Dicalcium phosphate *	...	22.88	17.48	...	...
Superphosphate, 20% *	...	17.88	8.74	...	...
Limestone (95% $CaCo_3$) *	...	38.00	...	...	...
Oyster shells (95% $CaCo_3$) *	...	38.00	...	...	...
Gypsum *	...	25.00	...	...	...
Wood ashes *	...	21.45	...	...	...
Common salt	...	...	...	39.37	60.63

when such a ration has added to it the simple mixture of two parts steamed bone meal, two parts ground limestone, and one part common salt, in an amount to represent 1½ percent of the ration, the supply of calcium and phosphorus will be adequate. A ration like 90 parts corn and 10 parts tankage contains sufficient calcium and phosphorus, and probably also of salt. Access to salt in a self-feeder, however, probably would be advisable in both these instances. When the protein supplement is half animal and half plant in origin, the supply of calcium and phosphorus is above the minimum amounts recommended. The addition of alfalfa meal to a corn—tankage—soybean-oil-meal ration, in an amount to equal 10 percent of the ration by weight, raises the calcium and phosphorus content practically to the maximum of the standard. When pigs have access to good forage and are receiving animal protein supplements there would seem to be no reason to anticipate any mineral shortage, except possibly of salt (see page 288).

Vitamins are necessary. The number of vitamins known to be necessary for the support of some phase of animal life is now placed at 15. The chemical nature of most of these has been determined, and their functional effects on growth and reproduction in swine studied (see page 54). Except in the case of vitamin E, which is necessary for reproduction but not known to be essential for growth, those vitamins of practical importance in maintaining reproductive efficiency are the same as those which are required to support good growth. These are vitamins A and D and, under certain feeding conditions, also some of those belonging to the so-called B-complex group, namely, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, choline, and B_{12}. There also are certain unidentified food factors, probably of a vitamin nature, which are known to be essential for maximum performance and which are supplied in insufficient amounts by many so-called balanced rations.

Vitamin A is necessary for the maintenance of health, growth, and reproduction. A deficiency in the supply of carotene (the plant precursor which produces vitamin A in the animal body) results in slow growth, lameness, muscular incoordination, and, in the case of breeding animals, also in breeding failures, and weak and dead pigs (see page 55). Owing to the ability of the pig which is fed on a ration rich in this vitamin to store up large body reserves, it may be months before any of these symptoms of deficiency appear during a succeeding period of deficit feeding.

Vitamin D, known as the antirachitic or "sunshine" vitamin, is essential for normal growth, especially of the bones. A deficiency in the ration, particularly when available sunlight is limited or/and with a limited supply of calcium or phosphorus or an unnatural balance or ratio between them, interferes seriously with the mineral metabolism, resulting in lameness, swollen joints, lowered blood calcium, rachitis, and osteomalacia. The ability of the pig to establish in his body useful body reserves of this vitamin is much more limited than in the case of vitamin A.

It is fairly well established now, through the studies of E. H. Hughes and associates at the California Station, and others, that the vitamins included in the B-complex group are essential in the diet of the pig. Their practical importance to the hogman, however, is less well known, although there is accumulating experimental evidence suggesting that in many feeding situations they require special attention.

The importance of vitamins to the practical feeder centers on the question of the likelihood of there being a deficiency in the supply of any one of them when good rations, made up of natural feeds, are fed; or/and whether or not the addition of an extra supply of one or more of them to a well-balanced ration will result in a boost to the rate and economy of the gains. Some experimental studies of these points are considered in the following chapter.

Vitamin content of feeds. Information concerning the vitamin content of feeds still is incomplete. In Table 45 is given the amount of carotene (Vitamin A) and most of the B-complex vitamins contained in 1 pound of the air-dry feeds, so far as it is known. The data were supplied by the Committee on Feed Composition of the National Research Council, and assembled by the Sub-Committee on Swine Nutrition.[28]

The feed sources of vitamin A or carotene, it is to be noted, are quite restricted. Little, if any, is found in the cereal grains or any of their by-products, excepting yellow corn; but all fresh green forage and choice hays are rich in it. Hay that has been cured under caps or artificially dried has many times the vitamin A value of hay that has been cured in the open. Hay that has been bleached or overexposed to the weather, or which has been long in the stack or mow, because of destructive oxidation by enzymes, will have its value seriously de-

[28] *Recommended Nutrient Allowances for Swine,* revised August, 1950; prepared by E. H. Hughes, W. M. Beeson, E. W. Crampton, and N. R. Ellis.

Table 45. Partial Composition of Some Hog Feeds (Air-dry Basis)

Feedstuffs	Vitamins per Pound Feedstuff				
	Carotene	*Thiamine*	*Riboflavin*	*Niacin*	*Pantothenic Acid*
	mgm.	mgm.	mgm.	mgm.	mgm.
Grain:					
Barley, excluding Pacific Coast	0.09	1.7	0.8	24.1	3.7
Barley, Pacific Coast	0.09	1.8	0.6	20.0	3.3
Corn (yellow)	1.33	1.7	0.5	9.8	2.6
Oats	0.05	2.9	0.4	8.2	6.8
Rye	0.04	2.0	0.7	7.1	4.2
Sorghum, kafir	0.13	1.6	0.5	18.3	5.7
Sorghum, milo	0.08	1.8	0.4	13.1	5.0
Wheat	0.04	2.3	0.5	28.8	6.4
Mill concentrates:					
Rice bran	...	10.3	1.4	129.1	10.3
Rice polishings	...	8.8	0.9	325.0	5.5
Wheat bran	0.04	3.9	1.4	63.5	13.6
Wheat standard middlings	0.08	5.8	0.8	44.3	9.3
Protein supplements (plant):					
Cottonseed meal (41%)	0.09	1.8	2.5	13.0	4.4
Linseed oil meal (33%)	0.12	3.9	1.9	18.9	7.5
Peanut oil meal (43%)	...	3.3	2.4	77.5	24.1
Soybean oil meal (44%)	0.10	0.8	2.0	16.7	6.1
Protein supplements (animal):					
Fish meal (63%)	...	0.08	4.3	29.9	4.0
Meat and bone scraps (50%)	...	...	2.1	21.4	1.5
Tankage, digester (60%)	...	0.14	1.2	19.2	1.2
Skimmed milk, dried	...	1.5	10.0	5.7	16.0
Meat scraps (meal 60%)	...	0.1	2.5	23.7	2.3
Miscellaneous:					
Alfalfa meal, sun cured (20%)	48.0	...	7.2	...	...
Alfalfa meal, dehydrated (20%)	60.0	3.1	7.4	17.3	18.5
Bone meal, steamed	...	1.0	0.7	2.0	1.5
Distillers' dried solubles	...	2.7	5.2	54.3	8.9
Molasses, beet	...	...	...	22.0	...
Molasses, cane	...	0.4	1.1	20.9	17.9
Whey, dried	...	1.8	...	5.1	22.4

pleted. The greenness of hay is a practical and reliable measure of its carotene content or vitamin A value.

Concerning vitamin D, which is not listed in the table, it may be said that the cereal grains and their by-products contain practically none. Hays that have been cured in the sun have a fairly rich supply. On the other hand, hays that have not been exposed to the sun after

cutting have little. Fresh forage as grazed has none. Resulting from the direct activating effect of sunlight, however, pigs on forage are in no need of an additional supply. The value of sunlight in the prevention and cure of rachitis is due to its chemical action on certain animal fats, chiefly ergosterol, which is located in the skin.

Because of the availability of fresh forage and sunshine there exists no vitamin A or vitamin D feeding problem during the summer. As a result of the short, dark days of winter, and the absence of both vitamins in most concentrated feeds, however, their supply is a matter of practical importance during this season. Rich commercial sources of these two vitamins are the oils extracted from the liver fat of marine fish, especially of the cod and halibut. By irradiating yeast with ultraviolet light an extremely concentrated source of vitamin D is obtained.

Nutrient allowances for swine. In Table 46 are given the latest recommendations of the subcommittee of the National Research Council [20] concerning the nutrient allowances for the different classes of

Table 46. Nutrient Allowances Recommended per Pound of Total Feed (Concentrate and Forage) for Swine

	Description of Pigs								
						Breeding Stock			
						Pregnant Females and Breeding Boars		*Lactating Females*	
	Market Stock					*Young Stock*	*Adults*	*Gilts*	*Adults*
Liveweight (lb.)	50	100	150	200	250	300	500	350	450
Expected daily gain (lb.)	1.0	1.6	1.8	1.8	1.8	0.75	0.5	...	...
Energy and protein									
Total digestible nutrients (lb.)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Crude protein (lb.)	0.18	0.16	0.14	0.13	0.12	0.15	0.12	0.15	0.15
Amino acids									
Tryptophan (gm.)	0.9	0.8	0.7	0.6	0.6	...	...	...	...
Lysine (gm.)	4.6	4.1	3.6	3.1	3.4	...	...	...	...
Methionine (gm.)	2.7	2.5	2.0	2.0	2.0	...	...	...	...
Inorganic nutrients									
Calcium (gm.)	3.0	3.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Phosphorus (gm.)	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Salt (NaCl) (gm.)	2.3	2.5	2.3	2.3	2.3	2.5	2.3	2.3	2.3
Vitamins									
Carotene (mg.)	0.75	0.75	1.0	1.0	1.0	3.0	3.0	3.0	3.0
Vitamin D (I.U.)	50	50	50	50	50	50	50	50	50
Thiamine (mg.)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Riboflavin (mg.)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Niacin (mg.)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Pantothenic acid (mg.)	4.5	4.5	4.5	4.5	4.5	...	...	...	...
Pyridoxine (mg.)	0.6	...	...	...	...	...	...	...	...

[20] *Ibid.*

hogs, including most of the vitamins belonging to the B-complex group.

Vitamin and other deficiency symptoms. The dietary deficiency symptoms listed in Table 47 are the ailments which have been observed in pigs when subjected to diets experimentally restricted in the respective nutrients.[30]

Some type rations. It will be of some interest here to study the four type rations which are recommended by this subcommittee[31] as examples of adequate diets for the growing and fattening pig. Diet No. 1 is adapted to Corn Belt conditions; Diet No. 2 to the Canadian provinces; Diet No. 3, particularly to the barley-growing areas; and Diet No. 4 to the South.

SOME OTHER IMPORTANT FACTORS

Thus far in this chapter attention has been given to the nutritional requirements of the growing and fattening pig. These include heat and energy furnishing feeds (carbohydrates and fats), proteins, minerals, and vitamins, each in an amount that will ensure a complete and balanced ration. For practical success, however, experience has shown the need of attention also to certain factors of a physical or economic nature. These are (a) bulk or fiber content, (b) palatability, (c) laxative properties, (d) effect on the quality of pork, (e) price or cost, and (f) the water supply.

by substituting unhulled for hulled oats resulted in reducing the daily gain from 1.25 to 0.95 pound, and in increasing the feed required for a unit of gain by 62 percent.

A large number of experimental studies have been made at the Wisconsin Station by Bohstedt and Fargo [34] and by Lathrop and Bohstedt [35] to determine the place of oat-mill feed in rations for growing and fattening pigs. This oat-meal by-product, made up mostly of oat hulls, contained on the average 27 percent of fiber. The rations were finely ground, allowed to soak in water between feedings, and fed by hand according to appetite twice daily. The basal ration consisted of ground corn or hominy feed balanced with the trio-mixture and a simple mineral supplement. Increasing proportions of the mill feed were fed in the different rations until a maximum of about 25 percent was reached. They found that no depression in the rate of gain occurred until the proportion was increased beyond a 16 percent level, with a fiber content of 7.5 percent for the ration as a whole. The amount of feed required for a given gain, however, increased regularly with rations containing more than about 4.5 percent of fiber. They concluded that, when fed to pigs in the dry lot in an amount to represent a fiber content in the ration of not to exceed 10 percent, oat-mill feed had a replacement value equivalent to 40 to 55 percent of the value of ground corn or hominy feed.

These results, it is to be understood, apply only to pigs fed full rations and for the period from soon after weaning to market weights. For the best development of pigs intended for the breeding herd the ration may contain very appropriately as much as 10 percent of fiber, particularly when the amount fed is not limited. Although the pigs will not gain as fast, the extra bulk will prove a safeguard against overfatness and broken-down pasterns and will make more certain that the development of the framework of bone and muscle will keep pace with the tendency to fatten.

Feeds most commonly fed to pigs are relatively low in fiber. Oats, wheat bran, rice bran, unhulled-peanut-oil feed, and oat-mill feed are not well adapted to full-fed pigs and can be successfully used only when their proportion in the ration is strictly limited. In Fig. 36 the fiber content of the common feeds is shown graphically. Also, there is shown the percentage of fiber contained in several widely fed rations. Although some proprietary or mixed feeds contain an excessive

[34] G. Bohstedt and J. M. Fargo, "Facts for Farmers." Bul. 425, 1933.
[35] A. W. Lathrop and G. Bohstedt, Res. Bul. 135, 1938.

Table 47. Clinical Symptoms of Dietary Deficiencies

Deficient Nutrient	Slow or Interrupted Growth	Reduced Appetite	Poor Hair and Skin Condition	Lameness and Stiffness	Diarrhea	Impaired Reproduction	Dead or Weak Offspring at Birth	Weakened Bone Structure	Anemia	Other Effects
Energy	+					+				Reduced fatness in proportion to body weight.
Protein level	+	+					+			Poor feed efficiency.
Protein quality (essential amino acids)	+	+								
Fats	+	+	+							Loss of hair; scaly, dandruff-like dermatitis, especially of feet and tail.
Calcium	+	+	+	+		+	+	+		Severe cases may show reduced serum calcium and tetany.
Phosphorus	+	+		+				+		Reduced inorganic blood phosphorus.
Sodium (as common salt)	+	+	+							Depraved appetite.
Iodine			+			+	+			Birth of hairless pigs, goiter.
Iron and copper	+	+	+			+			+	A disease of young pigs; high mortality, susceptibility to parasitic invasion, thumps.
Vitamin A	+	+		+		+	+			Night and day blindness, hyper-irritability.
Vitamin D				+				+		Rickets, enlarged joints, weak bones.
Thiamine	+	+			+		+			Slow pulse, low body temperature, flabby hearts.
Riboflavin	+	+	+	+	+		+			Crooked legs.
Niacin			+		+					Moderate slowing of growth, occasional vomiting, foul-smelling feces, pig pellagra.
Pantothenic acid	+	+	+	+	+					Incoordinated, wabbly gait (goose-stepping).
Pyridoxine	+	+	+	+	+				+	Epileptic-like fits, anemia, slowing of growth after first convulsion.

In general the applicable symptoms marked + for a given nutrient deficiency should be observed in the sick animal before a diagnosis is made that deficiency of that nutrient in fact exists or is the cause of the ill health of the pig.

Table 48. Examples of Diets for 100-pound Pigs

Item	Formula of Feed Mixture	Am't Mixture Daily per Pig	T. D. N.	Crude Protein	Calcium	Phosphorus	Salt	Carotene	Thiamine	Riboflavin	Niacin	Pantothenic Acid
		Lb.	*Lb.*	*Lb.*	*Gm.*	*Gm.*	*Gm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*	*Mgm.*
Recommended allowances		5.30	4.00	0.85	14.40	9.60	12.00	4.00	2.70	4.50	27.00	25.00
Ingredients	*Parts*											
Diet 1:												
Corn	60.0	3.18	2.48	0.29	0.32	3.91	...	4.23	5.41	1.59	31.16	8.27
Oats	15.0	0.80	0.50	0.10	0.33	1.56	...	0.04	2.32	0.32	6.56	5.44
Soybean oil meal..	14.0	0.74	0.58	0.33	1.01	2.22	...	0.07	0.59	1.48	12.36	4.51
Tankage	5.0	0.27	0.19	0.16	7.48	3.69	...	0.00	0.04	0.32	5.18	0.32
Alfalfa meal	5.0	0.27	0.09	0.05	2.01	0.39	...	12.96	0.84	1.94	4.67	5.00
Minerals	1.0	0.05	...	...	6.25	0.87	4.55	...	...	...	...	...
Total	100.0	5.31	3.84	0.93	17.43	15.64	4.55	17.30	9.20	5.65	59.93	23.54
Diet 2:												
Barley	45.0	2.39	1.72	0.31	0.98	5.09	...	0.45	4.06	1.91	57.60	8.84
Oats	40.0	2.12	1.34	0.25	0.87	4.13	...	0.11	6.15	0.85	17.38	14.42
Linseed oil meal..	6.0	0.32	0.23	0.11	0.64	1.37	...	0.04	1.25	0.61	6.05	2.40
Fish meal	1.5	0.08	0.00	0.05	2.07	1.20	...	...	0.01	0.34	2.39	0.32
Meat meal	4.5	0.24	0.17	0.15	6.86	3.81	...	...	0.02	0.60	5.69	0.55
Minerals	3.0	0.16	...	...	17.43	2.18	14.50	...	...	...	...	...
A + D oil	...	...	...	...	...	...	...	...	...	...	...	...
Total	100.0	5.31	3.52	0.87	28.85	17.79	14.50	0.60*	11.49	4.31	89.11	26.53
Diet 3:												
Barley (P. C.) ...	78.0	4.31	2.97	0.41	1.12	7.68	...	0.78	7.43	2.48	82.60	13.69
Tankage	3.0	0.16	0.11	0.10	4.44	2.19	...	0.00	0.02	0.19	3.07	0.19
Soybean oil meal..	12.5	0.66	0.52	0.29	0.90	1.98	...	0.07	0.53	1.32	11.02	4.03
Alfalfa meal	5.0	0.27	0.09	0.05	2.04	0.38	...	12.96	0.84	1.94	4.67	5.00
Bone meal	0.5	0.027	...	...	...	...	...	...	0.03	0.02	0.05	0.04
$CaCo_3$	0.5	0.027	...	...	7.89	1.44	...	...	...	...	...	...
Salt (NaCl)	0.5	0.027	...	...	...	...	12.00	...	...	...	...	...
Total	100.0	5.30	3.69	0.85	16.39	13.67	12.00	13.81	8.85	5.95	101.41	22.89

amount of fiber, most of them are within the limits of safety with respect to this point. A study of the records in the state chemist's office showed that of the 52 brands of hog and pig meals sold in Indiana from 1926 to 1933, the average fiber content was 7.68 percent, with a range from 4 to 14 percent. Only seven brands contained 10 percent or more of fiber and the protein content of these, with one exception, was 30 percent or more. Ten percent of fiber is not excessive when the feed in question is fed as a supplement to corn and in a proportion so as not to exceed one-fourth of the ration.

The swelling property of feeds. The importance of fiber as a factor in reducing the quantity of food which the small stomach of the pig can accommodate, is not, however, due to its bulkiness in the dry state, but rather to its bulk or volume in the stomach after ingestion. After the food reaches the stomach, it undergoes a soaking process which results in swelling and increased bulk. On soaking in water, some feeds swell very much more than others; in fact, some concentrated feeds, per unit of dry weight, have greater volume after soaking than others of considerably higher fiber content.

Proctor and Wright of Reading University, England,[36] were the first to call attention to the fact "that there was no evidence that different foods of the same weight of dry matter would occupy identical bulks in the stomach, even when attention was confined to concentrates alone, and that the practice of stating the capacity of an animal for food in terms of dry matter may be misleading."

They fed two high-swelling and two low-swelling rations, equally complete and balanced, individually and according to appetite to groups, each of four pigs, from a weight of 40 to 80 pounds by the "change-over" method. In the first test the volume of the two rations compared after soaking was 138:100; in the second test it was 162:100. In both trials the amount of dry feed consumed was significantly greater and the rate of gain faster on the low-swelling than on the high-swelling rations. But the total soaked volume consumed of the high-swelling ration exceeded the volume consumed of the low-swelling ration by 31 percent. Hence, it was concluded that the bulk of the high-swelling ration prevented the consumption of the amount of feed fully to satisfy the appetite and to make possible maximum gains.

In 1945 the author undertook a laboratory study of the swelling

[36] Frank Proctor and Norman Charles Wright, "Bulk in Animal Feeding." *Jr. Agr. Sci.*, Vol. 17, Part 3, p. 392, 1927.

property of our common concentrated feedstuffs.[37] Fifty-two varieties of feed, in triplicate, were subjected to a swelling test by soaking finely ground samples in water of a temperature of 38°F for a period of 2 to 4 hours. The results, summarized for the different classes of feeds, are shown in Table 49.

Table 49. Average Volume and Percentage Increase in Volume Due to Soaking, With Minimum and Maximum, of the Different Classes of Feeds

Feed	*Percentage Fiber Air-dry Feed*	*Volume in C.c. of 1 Gm. Air-dry Feed*	*Volume in C.c. after Soaking of 1 Gm. Air-dry Feed*	*Percentage Increase of Soaked Over the Dry Volume*
Oil Meals	8.3	1.36(1.20–1.59)	4.23(2.90–5.22)	210(142–293)
Meat and Fish Meals	1.6	1.28(1.09–1.42)	2.06(1.71–2.38)	61(40– 76)
Cereal By-products	6.75	1.73(1.36–2.05)	2.63(1.48–3.92)	51(0– 96)
Ground Grains	3.83	1.27(1.09–2.01)	1.86(1.56–2.45)	48(0– 90)
Whole Grains	...	1.23(1.12–1.45)	1.89(1.68–2.56)	53(40– 77)

The most striking fact revealed by these tests was that the oil meals as a class, although little higher in fiber content, showed approximately four times the swelling property of the other concentrates. Solvent-extracted linseed oil meal gave an increase of 293 percent over the dry volume; cottonseed meal, the lowest in this class, had an increase of 142 percent. The amount of water imbibed by the higher-swelling feeds was equal to that contained in many roots and other succulent feeds.

That the amount of fiber in a feed or ration is an unreliable measure of its bulkiness or volume after ingestion was shown by the extreme variations in volume after soaking among the feeds of similar fiber content. Wheat bran has a higher fiber content than linseed oil meal, but the percentage increase in volume because of soaking was 263 for the linseed and 71 for the bran. Oats contain nearly five times as much fiber as ground corn, but their soaked volume was practically the same. Ground rye was as bulky after soaking as ground oats, yet contains only one-fourth as much fiber.

The swelling property of a feed or ration is an important factor in determining its volume in the stomach after ingestion; the other factor

[37] W. W. Smith, "The Swelling Property of Feedstuffs," Ind. Exp. Sta. Cir., 320, 1947.

is the fiber content. Both are limiting factors of production, therefore, whenever the available nutrients supplied are less than the animal is capable of metabolizing for production.

Palatability is essential. No ration can be satisfactory if it is not palatable, particularly when fast gains and quick finish are desired. It is possible to have a ration which is ideal in all other respects, but if it lacks in palatability the pig will not consume it in the amounts necessary for either fast or economical gains. Usually, however, the better balanced and more complete a ration is, the more palatable it will be. Rations made up of a variety of feeds usually are more palatable than those composed of one or two feeds only, not because of the variety itself but rather because they are more likely to be more complete and better balanced.

Some feeds are more palatable than others of the same class because of individual peculiarities of flavor and physical qualities. Corn is much better liked than rye. Fresh feeds like mill and packing-house by-products and ground grains are more palatable than the same feeds after they have become stale. Grains that are infested with scab or other parasites are not as palatable as the clean grain. Also, rations are always relished most and eaten in largest amounts when the appetite is keenest. The skillful feeder can do much to maintain this keen "edge" by the way he feeds, as well as by the feeds he selects. He is careful always to limit the amount fed so that no feed will be left in the trough after a reasonable time to sour and contaminate subsequent feedings; he anticipates the effects of changes of temperature and weather on the appetite and varies the amount fed accordingly; and he feeds at regular times and is careful not to disturb the established routine in the habits of the pig.

the feed which is responsible for the effect it may have is not known definitely; that it is sometimes the result of certain mineral salts, the fiber content, natural water, or succulence seems fairly well established, however.

Effect on the quality of product. Another factor of considerable importance in feeding pigs for market is the possible effect which the ration, or some of the feeds in it, may have on the quality or firmness of the pork produced. American packers are more and more disposed to discriminate against hogs coming from sections known to use feeds which produce soft or oily carcasses, and to favor those produced by feeders that have the reputation of producing hogs that cut out firm carcasses. Feeds of a high-oil or fat content tend to produce soft or low-melting fats in the body; rations low in fats and high in carbohydrates, on the other hand, produce firm carcasses (see Chap. XV).

Feeds that have well-established reputations for producing soft or oily carcasses are the following: peanuts, soybeans, sunflower seed, chufas, and mast. Rice bran and rice polish also produce soft pork under certain feeding conditions. As a result of their comparatively low fat content, the cereal grains produce carcasses of acceptable firmness for the domestic trade when the hogs are marketed with sufficient finish. Barley is regarded by many "expert" feeders as possessed of special merit in the production of champion show carcasses.

Other factors in addition to the fat content of the ration are also important in affecting the firmness of the carcass, although to a lesser degree. The studies of Robison of the Ohio Station,[38] for example, showed that as hogs become heavier, from 100 to 250 pounds, their fat becomes firmer. When fed the same ration to the same weight, the fat of the faster gaining hogs was slightly firmer or less soft than the fat of the slower gaining hogs. Comparing the effects of full and limited feeding, he found that the full-fed, or rapid-gaining, hogs were as fat at 200 pounds as the limited-fed, or slower gaining, hogs were at 250 pounds. When at the same degree of fatness when slaughtered, regardless of the weight or length of time fed, there was little difference in firmness of the fat of the slow- and fast-gaining hogs fed the same ration.

So far as is known, none of the grains or standard plant or animal by-product feeds have any appreciable tendency to taint the flesh of pork. Instances have been reported, however, where a fishy flavor had been detected in bacon made from pigs which had been fed fish meal.

[38] W. L. Robison, Bul. 664, 1946.

resulting, no doubt, from the extra high oil content in the feed. German investigators have reported taints in the brain and liver of pigs fed fish meal.[39]

Tests conducted by Grummer and associates of the Wisconsin Station [40] showed that pork from hogs that had been liberally treated with benzene hexachloride, as used against mange and lice, was not contaminated when the treatment was applied 10 days before slaughtering. When applied immediately before slaughtering, however, an off-flavor in the lean and fat was detectible.

Effect of exercise on firmness of carcass. The amount of exercise taken by pigs during the growing and fattening period seems to affect the firmness of the carcass. In Indiana studies, covering three years, 50- to 60-pound pigs were fed to a weight of 225 pounds and, after slaughtering, their carcasses graded for firmness. Half was exercised by being driven a half mile twice each day; the other comparable half was confined in a small dry lot. The 59 pigs that were exercised produced 41 carcasses which graded Hard, 15 graded Medium Hard, and 3 Medium Soft. For those that were confined there were 29 Hard, 23 Medium Hard, and 7 Medium Soft. Back-fat thickness for the exercised hogs was 1.9 inches, and for those that were confined it was 2.01 inches.

Price or cost. Finally, there remains to be mentioned the factor of price or cost. Judged by the financial results, this factor deserves to stand second or first in importance. On the general run of hog farms the carbohydrates or fattening portion of the ration is supplied most economically in the home-grown grains. Under normal conditions it is rarely, if ever, advisable for the farmer to purchase proprietary or commercial mixed feeds designed to substitute for the home-grown products when these are available. Grains alone, however, do not supply all the constituents of a complete ration and feeds rich in protein or growth-producing properties commonly are not grown in sufficient amounts on the hog farm, especially in the Corn Belt, to balance the carbohydrate grains. Although good forage helps, resort must be had usually to some form of the commercial protein feeds on the market. The one which is cheapest according to price, composition, and general suitability should be chosen. In the purchase of protein supplements an important principle to adhere to is to prefer always, other things being equal, the feed which supplies the needed food

[39] *Nutrition Abstracts and Review*, Vol. IV, No. 2, Oct., 1934.
[40] R. H. Grummer, R. W. Bray and G. Bohstedt, *Jr. An. Sci.*, Vol. 9, No. 1, 1950.

material in the most concentrated form. This will make it possible for the ration to be made up most largely from home-grown sources. The cost of supplying the minerals which may be lacking in the ration may be reduced by using home-made rather than purchased mixtures.

The water supply. Water is indispensable to the life of the pig and a more important factor affecting the results in practical feeding than is generally appreciated. As an essential constituent of all the fluids and tissues, both soft and hard, it represents generally more than one-half the weight of the body. It is the vehicle in which the absorbed food is transported to the living cells and the waste products eliminated from the body. It is an important means for the regulation of the body temperature. All the processes of growth and repair, all cell activity, can take place only in the presence of water.

The amount of water needed to meet the physiological needs of the pig varies considerably. More is required in summer than in winter, more on full rations than on limited ones, and more on a protein-rich diet than one more carbonaceous in character. Young pigs require more water according to their weight than old pigs because they consume more feed per weight, their vital processes are more rapid, and because water is present more abundantly in their tissues.

Evvard of the Iowa Station [41] has made extensive tests to determine the water consumption of pigs of different ages and when fed different types of rations. The figures given in Table 50 represent his estimates based on these studies. They include the water taken in with the food as well as in drinking.

Methods of watering compared. On the usual dry-lot-fed grain ration, fed dry, the amount of water obtained in the feed amounts to about 5 percent of the total consumption for the young pig and about 10 percent for the 200-pound pig. A 100-pound pig fed 6 pounds of buttermilk or skim milk, with grain, would obtain from his ration more than one-half his daily water requirements.

Ferrin and McCarty of the Minnesota Station [42] compared two methods of watering growing-fattening pigs during the summer in two experiments. Lot I was watered by hand three times a day, being given all they would drink in 30 minutes. No water was left in the trough between these periods. The pigs in Lot II were provided with an automatic waterer, located close to the feeder. The pigs in both groups, numbering 10 in each lot, were self-fed a good ration of corn, mid-

[41] J. M. Evvard, Res. Bul. 118, 1929.
[42] E. F. Ferrin and M. A. McCarty, H-21 and H-29, 1925 and 1926.

Table 50. Water Consumption of Pigs on Full Rations

Assumed Weight of Pig	*Total Daily Water Consumption, Estimation per Cwt.*		*Water Required for Each Pound Dry Matter of Ration*	*Approximate Water Consumption, Freewill, Daily per Pig*	
	Spring Pigs	*Fall Pigs*		*Spring Pigs*	*Fall Pigs*
lb.	lb.	lb.	lb.	lb.	lb.
25	13.6	10.6	2.62	3.3	2.5
50	11.6	9.6	2.35	5.5	4.5
75	11.6	9.6	2.40	8.5	7.0
100	9.6	8.1	2.04	9.0	7.5
125	8.2	7.4	1.85	9.5	8.5
150	7.2	6.6	1.67	10.0	9.0
175	7.0	6.5	1.72	11.5	10.5
200	5.0	5.3	1.35	9.0	9.6
225	4.3	4.3	1.23	8.5	8.5
250	3.4	3.4	1.03	7.5	7.5
275	2.8	2.9	0.94	6.5	7.0
300	2.4	2.4	0.86	6.0	6.0
350	1.8	1.8	0.72	5.3	5.3
400	1.6	1.6	0.69	5.2	5.2

dlings, tankage, and minerals on rape pasture for a period of 80 days to a market weight of about 200 pounds.

The results from the two years when averaged showed no significant difference either in the rate or economy of gains. However, the pigs on the automatic waterer drank 25 percent more than those that were watered by hand three times a day.

Artificial lighting. It is generally accepted among commercial poultrymen that artificial lighting during the long winter nights results in increased egg production. The belief that a similar practice when applied to pigs that are self-fed would increase feed consumption and produce faster gains has resulted in its trial by a number of hogmen and of press reports that have been very favorable.

Ferrin of the Minnesota Station [43] made a test of the practice during a feeding period of 48 days, from January 14 to March 3, 1949. Two lots of fall-farrowed pigs of equal total weight, numbering 48 in Lot I and 38 in Lot II, were used in the experiment. In Lot I a clock switch turned on the lights from 10 to 11 P.M. and again from 3 to 4 A.M. in both the inside sleeping quarters and the outside pen where the self-feeder and waterer were located. Lot II was similarly housed and fed, but without lights. A well-balanced ration, self-fed, was available in both lots.

[43] E. F. Ferrin, Mimeo. Rpt., 1949.

When the lights were turned on, most of the pigs in Lot I got out of their beds, ate some feed, and drank some water, but after two or three weeks some of the pigs had become indifferent to the light and the noise of the banging feeder lids. It also was observed that the pigs in Lot II, which may have been aroused by the noise in Lot I, ate feed and drank water at the same time; however, they had been observed eating at night before the experiment began. Considering the difference in size of the pigs in the two lots, it was concluded that the artificial lights did not seem to influence either the rate of gain or the amount of feed required to produce a given gain.

At the Illinois Station Terrill and associates [44] ran a similar test with two lots of 20 pigs each on brome-grass—alfalfa pasture, self-fed a well-balanced ration from an initial weight of 36 pounds to one of about 200 at the finish. Two 150-watt bulbs were automatically turned on from 10 to 11 P.M. and 3 to 4 A.M. in Lot I during the entire period. These lights were so situated that they did not shine on the comparable Lot II. The results showed that "night lights used in this experiment did not significantly affect the rate of gain, average daily feed consumption, or feed consumed per 100 pounds of gain."

Summary. It will be profitable now to re-enumerate the factors which have been mentioned. The ration should be complete chemically, as shown by the amounts and proportions of the carbohydrates and proteins, the presence of a minimum of certain essential fats, by the quality of the proteins, the amount and variety of mineral salts contained, and the supply of vitamins. Also, to be satisfactory, the ration of the pig should not be too bulky, it should not produce soft or oily carcasses, it should be palatable, mildly laxative, and economical as to cost. With such a ration a skilful feeder who appreciates the importance of a good water supply, sunshine, quiet, comfortable surroundings, and regularity may look for maximum returns at minimum costs.

[44] S. W. Terrill, J. L. Krider, G. W. Sherritt, F. M. Crawford, and D. M. Baird, Mimeo. Rpt. AS 152, 1950.

VIII *Food Deficiencies of the Cereal Grains*

Thirty-five years ago the hogman fed little in addition to corn or other cereals. The general method of feeding and management employed by the Corn Belt farmer at that time was about as follows: The sows were bred to farrow in the late spring or early summer and, with their pigs, were soon out on grass. After weaning the pigs were allowed a very limited amount of corn or other grain throughout the summer and were given the run of a wood lot, when this was available, and natural pasture. Heavy grain feeding did not commence until the new corn crop was fairly mature, but from October on throughout the winter the pigs, in more or less confined quarters, were fed all the ear corn they would take until they were ready for market the following spring or early summer. Here and there were to be found observant feeders who fed in addition to corn some mill feed, wood ashes, charcoal, or salt.

Old ways are not the best. These methods secured for the young pigs during the summer the benefits of plenty of exercise, the opportunity to root, and a variety of green feed, with the result that, although their gains were slight and many of them stunted in development, they had by autumn an accumulation of mineral and vitamin reserves sufficient to enable them to make fair gains during the following winter on corn alone. Before spring arrived, however, there were invariably evidences of faulty nutrition. Under the best of these conditions the appetite became depraved, there were many cases of scurfy skin, the gains generally were slow, and the amount of corn required to produce a unit of gain excessive. When the winter was long, more severe cases of malnutrition such as stiffness, enlarged joints, staggering gait, rickets, paralysis of the hind quarters, and even death were common.

Although the feeding period has been considerably shortened, there

still are many farmers who persist in trying to grow and fatten pigs on corn or other grain alone, despite the contrary evidence both of experimental study and practical experience.

These ailments develop in pigs fed an exclusive grain ration like corn because corn is lacking in several food substances which are essential for complete nourishment. Corn and the other cereals are especially deficient in the constituents which promote growth. They are lacking in the amount and variety of their proteins and deficient in mineral matter (ash)—particularly calcium or lime and common salt—as well as the more recently appreciated food factors, the vitamins.

To give the scientific support on which these conclusions are based and to illustrate the methods employed by the investigator of feeding problems, attention will be given to a brief review of some of the more fundamental experimental studies which have been made of these points. What follows will serve also to bring to our attention some of the new discoveries in animal feeding as well as to emphasize their practical significance.

CORN IS DEFICIENT IN PROTEIN

The amount of protein is a limiting factor in growth. That the limited protein content of corn is one of the principal reasons why it cannot be depended on as a sole feed for growing pigs has been repeatedly shown by hundreds of practical experimental tests. Of all these, none has demonstrated the fact more clearly or positively than the one planned and carried through by the late Doctor Waters and associates at the Kansas Station.[1]

In each of four years, starting in 1911, one lot of weanling spring pigs of March and April farrow was fed a ration of corn alone, another similar lot corn and minerals (ash), and the third and fourth lots corn supplemented with various forms of milk and blood proteins, with and without minerals. At the beginning of the tests the pigs ranged in weight from 30 to 50 pounds and the four experiments covered periods of 280, 187, 180, and 200 days, respectively. The pigs were confined to cinder-covered dry lots and were supplied with tap water. They were hand-fed individually twice daily, the amount given being determined by what they would clean up. The corn was yellow and fed as a meal. The minerals were a superior mixture rich in a supply of calcium, phosphorus, chlorine, and iron, and fed mixed with the

[1] H. J. Waters, *Proc. Soc. Prom. Agr. Sci.*, 1914.

ground corn in amounts equal to 2 percent of the corn by weight. In one experiment milk ash was fed. There were but three pigs to each lot, but the integrity of the results was safeguarded by three repetitions of the experiment, by taking feed and gaining records of the individual pigs, the selection of litter-mates only for the different lots, and by making chemical studies of the rations and some of the carcasses at the close of the experiments.

It will be our purpose to consider here the results only from the lots which were fed corn and ash, on the one hand, and corn and ash with a protein supplement, on the other. These rations were practically alike except that in the corn-alone ration the protein supply was very low, while in the ration containing a supplement the protein supply was high. The supply of minerals was believed to be adequate in both cases. The figures given in Table 51 are the averages based on the four-year study.

Table 51. Protein as a Limiting Factor in the Growth of Pigs Fed Corn

Rations	*Average Percentage Crude Protein*	*Average Beginning Weight per Pig*	*Average Final Weight per Pig*	*Average Daily Gain per Pig*
		lb.	lb.	lb.
Corn and ash	8.6	45	78	0.16
Corn and ash + protein supplement	16.5	45	305	1.24

These pigs were fed for a period exceeding seven months, on the average, during which time those which received no protein in addition to corn gained an average of only 33 pounds per head. In the second experiment the pigs on this ration weighed just 1 pound more when the test was finished than when it was begun! Those which received protein, on the other hand, made an average daily gain of 1.24 pounds and at the close of the experiment averaged 305 pounds.

In discussing the results, Doctor Waters made the following observations: "In every case the amount of feed consumed by the pigs fed corn alone, corn and ash, and corn and protein-free milk was small. In some cases it was less than was required to sustain life, and death from starvation ensued. In most other instances, it was little more than the amount required for maintenance and, as already shown, little gain in live weight or of body substance was made. The animals seemed to be hungry and apparently were not satisfied after

they had eaten their meal. They would eat paper, wood, and almost any other unpalatable substance that might come within reach."

The pigs fed the unsupplemented rations consumed considerably less ash than did those receiving the balanced rations, especially in the first two experiments; but since minerals were fed in each case, in addition to those contained in the feeds, and natural water provided, with a run of cinder-covered outside lots, the conclusion seems inescapable that the wide contrast in the results was due chiefly to the additional protein supplied in the better balanced ration.

Corn alone for fattening well-grown pigs. The pigs in the above experiments weighed but 45 pounds when the trials began. Since the amount of protein needed to meet the body demands in proportion to the other food nutrients decreases as the age of the pig increases, it might be supposed that well-grown pigs being finished for market would do very well on corn alone. That this is not the case has been repeatedly shown by experimental tests.

In Table 52 there are brought together the summarized results of 35 feeding trials where the pigs used averaged 118 pounds at the start and the time covered by the feeding period averaged 80 days. In each trial corn alone was fed in one lot, while corn and a protein supplement was fed in the other. The protein was supplied as a single feed, in some cases animal and in others plant in character. In several of the experiments additional minerals were fed in both lots. During the months just prior to the experiments the pigs in most cases were on grass or special forage crops.

Table 52. Corn Alone versus Corn and a Protein Supplement for Fattening Well-grown Pigs
(Average 35 Experiments)

Ration	*Average Percentage Crude Protein*	*Average Initial Weight per Pig*	*Average Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*[a]
		lb.	lb.	lb.
Corn	8.6	118	0.96	544
Corn + protein supplement	15.0	118	1.46	436

[a] Skim milk and buttermilk were reduced to the weight of the other supplements by dividing by 5.

The pigs which received a protein supplement along with their corn made their gains at a rate more than 50 percent faster than those get-

ting no supplement. This means that the lots fed corn alone had to be continued on feed for a period of about 40 days after the close of the experiments before reaching the same market weight as the other lot. Of even greater importance than this, however, was the fact that those fed the protein supplement along with the corn made their gains at a very much lower feed cost. For producing a given increase in weight, 80 pounds of the better balanced ration proved equal to 100 pounds of the ration of corn alone.

These pigs at the beginning of the experiments were fairly well grown and, in most instances, their bodies probably were well fortified with mineral and vitamin reserves. These facts, along with the short feeding period and the opportunity to root for a portion of the time, enabled the pigs, which were restricted to straight corn, to make as good gains as they did.

In both these experiments the effect of adding the protein supplements was to make the rations more complete, to satisfy more nearly all the food demands, with the result that the pigs were more thrifty, their appetites were stimulated, and the consumption of feed greatly increased. One of the reasons why those receiving the supplemented rations made their gains on less feed was because the greater feed consumption resulted in a larger proportion of the ration being made available for gains after maintenance needs were satisfied. Another reason was that the unbalanced character of the corn-alone ration, together with the impoverished state of bodily vigor which it brought about, resulted in the available nutrients from the better ration being used more efficiently.

Normal development not possible on corn alone. In one of the first pig-feeding experiments in this country to be adequately supported by chemical analyses of the products of growth, Forbes of the Ohio Station [2] concluded his study of the harmful effects of a ration of corn alone with the following significant observations:

they had eaten their meal. They would eat paper, wood, and almost any other unpalatable substance that might come within reach."

The pigs fed the unsupplemented rations consumed considerably less ash than did those receiving the balanced rations, especially in the first two experiments; but since minerals were fed in each case, in addition to those contained in the feeds, and natural water provided, with a run of cinder-covered outside lots, the conclusion seems inescapable that the wide contrast in the results was due chiefly to the additional protein supplied in the better balanced ration.

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The muscles of corn-fed pigs are high in fat, and low in protein and in water; but the percentage of water in the fat-free meat is decidedly high. The proportion of ash to protein in the flesh of corn-fed pigs, however, is not low.

The livers of corn-fed hogs are small and low in ash and in phosphorus. Compared with rations containing more protein, corn produces small, fat kidneys. . . . The bones likewise are small, and lacking both in density, as indicated by ash content, and in breaking strength.

Kind of protein supplements important. Attention was called in the previous chapter to the fact that protein feeds of animal origin supplemented corn and the other cereals more efficiently than do those of plant origin. One probable reason for this is that feeds of animal origin, such as tankage, meat and bone scraps, fish meal, skim milk and buttermilk, contain a larger proportion of some of the particular amino acids which the grains lack. The other reason, and probably of equal importance, is the presence in the animal products of larger amounts of the essential minerals and vitamins.

Animal compared with plant supplements. To summarize in a general way data showing the superior supplementing qualities of animal- as compared with plant-protein feeds when fed with yellow corn to growing and fattening pigs in the dry lot, there are given in Table 53 the results of 24 experiments.[3] In 18 of the trials soybean oil meal was the plant supplement fed, and in 6, linseed oil meal. The tankage fed in most instances was of a high-grade variety, varying in protein content from 50 to 60 percent. The soybean oil meal fed had, on the average, 42 percent protein and the linseed oil meal 35 percent. The rations were full or self-fed in all cases until practically market weights were reached. A simple mineral mixture was fed in both lots.

The pigs fed the tankage consumed 14 percent more feed and gained at a rate 16.6 percent faster than those fed either the soybean or linseed meal. However, there was little difference in the amount of feed required to produce a unit of gain. The superior character of the tankage ration was expressed in its greater palatability, the result, in part, to better quality in the protein supply, and more especially, to the fact that it was less deficient in certain important B-complex vitamins, including the A P F factors, than the supplements of plant origin. More critical recent studies have shown that neither ration is complete. For extended periods of dry-lot feeding, especially in the winter months, both rations require further supplementation (see page 219).

[3] W. P. Snyder and W. J. Loeffel, Nebr. Exp. Sta., Bul. 243, 1930; E. G. Godby and A. L. Durant, So. Car. Exp. Sta., Bul. 234, 1926; W. L. Robison, Ohio Exp. Sta., Bul. 349, 1921, and Bi-monthly Bul. 223, 1943.

Table 53. Animal versus Plant Supplements for Growing and Fattening Pigs in the Dry Lot
(Average 24 Experiments)

Ration	*Initial Weight per Pig*	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Corn + tankage + minerals	61	5.27	1.33	Corn	361
				Tankage	35
				Total	396
Corn + soybean or linseed meal + minerals	61	4.63	1.14	Corn	362
				Soybean or linseed oilmeal	44
				Total	406

Tankage and soybean oil meal compared on pasture. When fed with corn on pasture the better plant supplements are about as efficient as tankage or meat scraps; that is, a pound of protein in the plant product is equal to a pound of the protein in the animal feed. This is illustrated by the results shown in Table 54 which summarizes 15 experiments in each of which one lot of pigs from soon after weaning was fed to market weights on pasture a ration of corn, high-grade tankage and minerals, and a comparable lot the same except that soybean oil meal was fed in place of tankage.[4] Expeller soybean meal was fed in all cases except in one in which it was the "toasted-extracted" variety. The pasture in most instances was alfalfa or a mixture of alfalfa and clover; in four it was rape. Full rations were fed in all cases according to appetite. In some the supplement was mixed with the ground corn in regulated amounts, in others it was self-fed, free-choice. A simple mineral mixture was fed to both lots.

Table 54. Tankage versus Soybean Oil Meal for Growing and Fattening Pigs on Pasture
(Average 15 Experiments)

Ration	*Initial Weight per Pig*	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Corn + tankage + forage + minerals	58	5.17	1.40	Corn	332
				Tankage	33
				Minerals	4
				Total	369
Corn + soybean oil meal + forage + minerals	58	5.34	1.44	Corn	313
				Soybean oil meal	51
				Minerals	7
				Total	371

In all cases the rations were full or self-fed. Linseed oil meal was fed in 17 of the trials, cottonseed meal in 11, and soybean oil meal in 7. The forage was alfalfa, clover or rape. Minerals were fed in most cases. The pigs average 63 pounds at the beginning and a little over 200 at the finish of the trials.

Table 55. Tankage versus Tankage Plus a Plant Supplement for Pigs on Pasture
(Average 35 Experiments)

Ration	*Initial Weight per Pig*	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Corn + tankage + forage	63	5.31	1.50	Corn	332
				Tankage	22
				Total	354
Corn + tankage + plant supplement + forage	63	5.33	1.49	Corn	327
				Tankage	15
				Plant sup.	16
				Total	358

From these last two series of experiments it appears that any differences in the supplementing efficiency of animal protein feeds such as tankage or meat scraps, and plant supplements, largely disappear when fresh green forage is added to the diet.

The "trio" or "trinity" mixture an early improvement. An important early step in the evolution of improved rations for growing and fattening pigs in the dry lot was the development by Morrison and associates of the Wisconsin Station [5] of the supplement which is known as the "trio" or "trinity" mixture. This consists of 50 percent tankage, 25 percent linseed oil meal, and 25 percent ground alfalfa hay.

In three early trials with 52 pound pigs fed in the dry lot to a weight of 200 pounds, the trio-mixture proved significantly superior to tankage alone as a supplement to corn. The gains were faster, less feed was required to produce a unit of gain, and the pigs were uniformly more thrifty under winter-feeding conditions. Several of the pigs in the lots which received tankage alone exhibited symptoms of rachitis. Later studies at the Wisconsin and other stations have indicated that the difference in the results was due chiefly to food factors of a vitamin character contained in the alfalfa hay, which constituted 5 percent of the ration.

The results of four experiments conducted by Willman and Morrison of the New York Cornell Station [6] with fall pigs fed in the dry lot under controlled conditions showed that a ration of yellow corn, digester tankage, linseed meal, field-cured alfalfa hay (5 percent), a simple mineral mixture, and salt was not significantly improved by the addition of cod-liver oil or fortified cod-liver oil. Keith and Miller of the Pennsylvania Station [7] also found that the addition of 1 percent of cod-liver-oil concentrate to a ration containing 15 percent of protein and composed of yellow corn, low-protein tankage, soybean oil meal, and alfalfa hay, when fed individually to pigs in the dry lot, from beginning weights of 48 and 53 to final weights of 156 and 176 pounds, was without beneficial effects.

The failure of cod-liver oil to improve the "trio" or similar mixtures when fed as a supplement to yellow corn to pigs in the open dry lot suggests that vitamin A was adequately provided in the basal ration, and that the sunshine available was sufficient to supplement any deficiency of vitamin D.

linseed without lowering the efficiency of the mixture. Cottonseed meal has a slightly lower value than linseed meal. Such other plant supplements as wheat shorts or middlings, ground raw soybeans, or corn germ meal or feed, have proved much less satisfactory in such a mixture than linseed or soybean oil meal.

That the advantage of the trio-mixture over tankage alone in dry-lot feeding is due mainly to the alfalfa is suggested by subsequent studies made at the Ohio, Kansas, Minnesota, and Wisconsin Stations, results of which were published from 1927 to 1932. At these stations 13 comparisons, in all, were made of the ration of corn, tankage, and alfalfa hay with one made up of corn, tankage, linseed oil meal and alfalfa hay when full or self-fed to pigs in the dry lot from an average of 60 pounds to market weight. The ratio of tankage to linseed meal in the latter rations varied from 1:1 to 2½:1, which approximated fairly closely the ratio in the trio mixture. The alfalfa hay constituted approximately 4 percent in the two rations. Additional minerals were available in most of the tests. The rations were the same except that linseed oil meal replaced part of the tankage in the ration under test.

The results in rate and economy of gains were practically identical. The daily gains were 1.29 and 1.30 pounds, and the amount of feed required to produce 100 pounds of gain was 424 and 421 pounds, respectively. In three of the trials tankage alone gave slightly better results than the mixture of tankage and linseed, while in three others the results were slightly in favor of the mixture. In the other seven trials the results were practically the same. The two rations were equally palatable and were consumed in the same amounts. The protein content of the rations also was the same.

Alfalfa hay improves winter rations. In a well-designed experiment carried through by Ellis and associates of the U.S. Department of Agriculture [8] valuable information is supplied concerning the merits of good-quality legume hay when fed as an addition to a ration of ground yellow corn, digester tankage, linseed oil meal, and minerals to fall-farrowed pigs during the winter, and also the proportion of hay that may safely be incorporated in the ration without affecting seriously the rate or economy of the gains. During two winters, 1936 to 1937 and 1937 to 1938, five lots of eight pigs each were fed the basal ration and varying proportions of ground No. 2 grade alfalfa hay, as shown in Table 56. The proportions of corn and tankage were so adjusted that the rations compared had the same protein and energy content.

[8] N. R. Ellis, J. H. Zeller, and J. X. King, A.H.D. No. 60, 1943.

A reduction in the protein supply was made in each lot when the pigs reached an average weight of 125 pounds by increasing the proportion of corn to tankage. The pigs were confined to concrete-paved lots, and fed from weights of 45 to 63 pounds to a final weight of 225 pounds.

Table 56. Alfalfa Hay in Different Proportions for Winter-feeding Growing and Fattening Pigs
(Average 2 Experiments)

Ration Constituents	*Percentage in Lot* 1	2	3	4	5
Ground alfalfa hay	0	5	10	15	20
Mineral mixture	1	1	1	1	1
Linseed meal	4	4	4	4	4
Tankage—to 125 lb.	11.8	11.2	10.6	10.0	9.4
Tankage—after 125 lb.	6.0	5.7	5.4	5.1	4.8
Ground yellow corn—to 125 lb.	83.2	78.8	74.4	70.0	65.6
Ground yellow corn—after 125 lb.	89.0	84.3	79.6	74.9	70.2
Calculated fiber content	2.25	3.64	5.04	6.44	7.84
Daily rate of gain, pounds	1.59	1.74	1.72	1.64	1.56
Feed required for 1 cwt. gain: Concentrates, pounds	358	358	339	335	324
Feed required for 1 cwt. gain: Hay, pounds	0	19	38	59	81

A decided improvement in rate of gain was shown by the pigs which received up to a level of 15 percent of alfalfa compared with those on the check ration containing no alfalfa. Maximum gains were made at the levels of 5 and 10 percent. At the 10 percent level 1 pound of concentrates was saved for each 2 pounds of alfalfa; at the 15 and 20 percent levels, approximately 2½ pounds were required for each pound of concentrates saved.

digestible nutrients obtainable by the pig from a given weight or volume of the ration declines. From the above results it would appear that as much as 10 or even 15 percent of good-quality alfalfa hay may be incorporated, which would mean a fiber content for the ration of 5 to 6½ percent, without seriously impeding the rate of gain (see page 177).

The same investigators made similar studies of *sericea lespedeza* hay, in 1938 to 1939 and 1939 to 1940, and of soybean hay, in 1940 to 1941 and 1941 to 1942 according to the same general plan. Although the results from the different years are not strictly comparable, the *lespedeza* showed a somewhat lower value than alfalfa, while the replacement value of soybean hay appeared to be somewhat higher than the alfalfa.

Kirk and Crown of the Florida Station [9] found in three experiments by adding alfalfa leaf meal in amounts of 2, 4, 6, 8, and 10 percent, respectively, to the basal ration of yellow corn, tankage, and minerals that the rate of gain was increased from a daily gain of 1.36 pounds on the check ration to 1.59 on the ration containing 8 percent of leaf meal. The total feed required for a unit of gain was practically the same, which gave to 1 pound of leaf meal the value of 1.1 pounds of corn. These trials were conducted under controlled dry-lot conditions with feeder pigs which averaged around 80 pounds at the start, and covering periods of 62, 61, and 98 days.

Complex mixed supplements in dry lot. In an effort to develop a more efficient supplement for market pigs, Vestal of the Indiana Station [10] began a series of experiments in 1937 and continued through 1941, in which studies were made of various combinations of animal and plant protein feeds. In Table 57 are given the average results secured when the best of these for dry-lot feeding, Purdue Supplement 5, was compared with a simple supplement composed of 90 percent meat and bone scraps and 10 percent alfalfa leaf meal. Purdue Supplement 5 is a complex mixture made up of 20 percent meat and bone scraps, 20 percent menhaden fish meal, 40 percent soybean oil meal, 10 percent cottonseed meal, and 10 percent alfalfa leaf meal. These rations were compared in four winter and four summer dry-lot trials with high-grade Duroc pigs fed from an average starting weight of 67 pounds to market weight. The shelled corn, supplements, and minerals were self-fed, free-choice.

[9] W. G. Kirk and R. M. Crown, Bul. 428, 1947.
[10] C. M. Vestal, Bul. 508, 1946.

Table 57. Meat and Bone Scraps Compared with Complex Supplement 5, Dry Lot
(Average 8 Experiments)

Rations	*Initial Weight*	*Daily Feed Consumption*	*Daily Gain*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Sh. y. corn, self-fed, + meat and bone scraps 90%, Alfalfa leaf m. 10%, self-fed, + minerals, self-fed	67	5.62	1.38	Corn	365
				Supplement	42
				Minerals	0.4
				Total	407.4
Sh. y. corn, self-fed, + Purdue Supplement 5, self-fed, + minerals, self-fed	67	6.35	1.70	Corn	333
				Supplement	40
				Minerals	0.8
				Total	373.8

In every year, the pigs which received Purdue Supplement 5 gained faster and used their feed more efficiently. They ate 13 percent more feed daily, gained 23 percent faster, and made a unit of gain on 8 percent less feed. Also, these pigs were generally more uniformly finished.

It is worthy of note that, although the amount of alfalfa leaf meal provided represented only 1 percent of the rations, the pigs in both lots remained thrifty during the entire period. At no time in any of the eight experiments was there observed any evidence of skin trouble, lameness, stiffness, or lack of thrift. In this connection it is important to note that these pigs were on rye or alfalfa pasture up to weaning time, and on alfalfa pasture from the time they were weaned until they went into the experimental dry lots at an average weight of 67 pounds.

Other studies by Vestal, made under the same experimental conditions, showed that when the fish meal of Supplement 5 was wholly replaced by meat and bone scraps, by increasing the percentage of the latter in the supplement from 20 to 40, the results were considerably less satisfactory. When half the fish meal was replaced by increasing the meat and bone scraps from 20 to 30 percent, the results in rate and economy of gains were practically identical, based on the averages of three experiments. In three other trials replacing one-half of the fish meal with dried skim milk proved equally satisfactory. In five experiments Vestal found that the simpler supplemental mixture composed of 40 percent meat and bone scraps, 50 percent soybean oil meal, and 10 percent alfalfa leaf meal was somewhat less valuable than Supple-

ment 5, as shown by the difference in daily rate of gain of 1.54 and 1.70 pounds, and of feed required to produce 100 pounds of gain of 380 and 369 pounds, although the results were more satisfactory than those fed the supplement of the check ration made up of 90 percent meat and bone scraps and 10 percent alfalfa leaf meal.

Aubel of the Kansas Station [11] compared various complex mixtures of protein feeds with tankage and alfalfa hay for pigs fed in the dry lot from 70 pounds to market weight. All of the mixtures proved somewhat better than the supplement of tankage and alfalfa alone, although the amount of alfalfa supplied in the latter amounted to 6 percent of the ration, while in the complex mixtures it represented less than 1½ percent. The fastest and cheapest gains were made with the supplement composed of 20 percent of tankage, 20 percent fish meal, 50 percent soybean oil meal, and 10 percent alfalfa hay.

Robison of the Ohio Station [12] in three dry-lot experiments, found that the supplement of equal parts soybean oil meal and tankage was fully equal to one composed of equal parts linseed meal and tankage for balancing corn, each ration containing about 4 percent of alfalfa meal and minerals. Also, in four trials he secured faster and cheaper gains when the supplement was made up of equal parts soybean oil meal and tankage than when they were mixed in the ratio of two parts of soybean oil meal to one of tankage.

In a 94-day dry-lot experiment with fall pigs of an average initial weight of 58 pounds, Weaver of the Missouri Station [13] compared tankage with various combinations of tankage, linseed meal, cottonseed meal, and shorts as supplements to a corn-mineral ration. The results showed no significant differences either in the rate or economy of gain due to the supplements fed.

Complex supplements on pasture. Any difference in favor of the complex mixtures of animal and plant supplements over the more simple ones, such as the trio or similar combinations, when fed in the dry lot, would be expected largely to disappear under pasture conditions. This is so because of the demonstrated richness of fresh green forage in those food factors of a vitamin character, some of which probably are lacking in sufficient amounts in dry-lot rations to meet fully the nutritional requirements. In fact, there are present in fresh forages desirable food factors which still are unidentified.

[11] C. E. Aubel, Cir. 207, 1941.
[12] W. L. Robison, Monthly Bul. 223, 1943.
[13] L. A. Weaver, Mimeo Rpt., Apr., 1942.

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Table 58. Meat and Bone Scraps Compared with More Complex Supplements on Alfalfa Pasture
(Average 8 Experiments)

Rations	*Initial Weight*	*Daily Feed Consumption*	*Daily Gain*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Shelled corn, self-fed, + meat and bone scraps, self-fed	68	5.60	1.62	Corn	327
				Supplement	18
				Minerals	0.7
				Total	345.7
Shelled corn, self-fed, + meat and bone scraps ½, soybean oil m. ½, self-fed	68	5.90	1.70	Corn	317
				Supplement	29
				Minerals	0.9
				Total	346 9
Shelled corn, self-fed, + Supplement C, self-fed	68	6.13	1.77	Corn	310
				Supplement	35
				Minerals	1 4
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The only advantage which the more complex Supplement C can claim over the more simple ones in these experiments is that it proved more palatable and the gains were somewhat more rapid. The total dry feed required for 100 pounds of gain was the same for all lots. Because of the overconsumption of Supplement C, however, the feed

[14] C. M. Vestal, Bul. 503, 1946.

ment 5, as shown by the difference in daily rate of gain of 1.54 and 1.70 pounds, and of feed required to produce 100 pounds of gain of 380 and 369 pounds, although the results were more satisfactory than those fed the supplement of the check ration made up of 90 percent meat and bone scraps and 10 percent alfalfa leaf meal.

Aubel of the Kansas Station [11] compared various complex mixtures of protein feeds with tankage and alfalfa hay for pigs fed in the dry lot from 70 pounds to market weight. All of the mixtures proved somewhat better than the supplement of tankage and alfalfa alone, although the amount of alfalfa supplied in the latter amounted to 6 percent of the ration, while in the complex mixtures it represented less than 1½ percent. The fastest and cheapest gains were made with the supplement composed of 20 percent of tankage, 20 percent fish meal, 50 percent soybean oil meal, and 10 percent alfalfa hay.

Robison of the Ohio Station [12] in three dry-lot experiments, found that the supplement of equal parts soybean oil meal and tankage was fully equal to one composed of equal parts linseed meal and tankage for balancing corn, each ration containing about 4 percent of alfalfa meal and minerals. Also, in four trials he secured faster and cheaper gains when the supplement was made up of equal parts soybean oil meal and tankage than when they were mixed in the ratio of two parts of soybean oil meal to one of tankage.

In a 94-day dry-lot experiment with fall pigs of an average initial weight of 58 pounds, Weaver of the Missouri Station [13] compared tankage with various combinations of tankage, linseed meal, cottonseed meal, and shorts as supplements to a corn-mineral ration. The results showed no significant differences either in the rate or economy of gain due to the supplements fed.

Complex supplements on pasture. Any difference in favor of the complex mixtures of animal and plant supplements over the more simple ones, such as the trio or similar combinations, when fed in the dry lot, would be expected largely to disappear under pasture conditions. This is so because of the demonstrated richness of fresh green forage in those food factors of a vitamin character, some of which probably are lacking in sufficient amounts in dry-lot rations to meet fully the nutritional requirements. In fact, there are present in fresh forages desirable food factors which still are unidentified.

[11] C. E. Aubel, Cir. 207, 1941.
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cost of the gains was highest in this lot, and lowest in the lot which received meat and bone scraps alone. The extra pounds consumed of the more complex supplements replaced only an equal number of pounds of corn.

Results secured by Robison of the Ohio Station[15] in two similar experiments, conducted in 1932 and 1933, were less favorable to the complex mixture. He compared tankage alone with a mixture made up of tankage, fish meal, dried skim milk, cottonseed meal, soybean oil meal, and linseed meal. Shelled corn was fed in one experiment and ground corn in the other. The pigs were on clover or rape, and were fed from an average starting weight of 58 pounds to a final weight of about 210 pounds. The average daily rate of gain for the lot receiving tankage alone was 1.27 pounds; for those receiving the complex mixture it was 1.26 pounds. The amount of feed, not including the forage, required to produce 100 pounds of gain was 344 and 345, respectively. Two later trials by Robison, in 1939 and 1940, gave results which slightly, but not significantly, favored the pigs fed the complex mixture.

Self-feeding complex supplements not always advisable. When a complex mixture of high-class animal- and plant-protein feeds similar to the above is self-fed free-choice along with corn, it often results, because of its palatability, in unnecessarily heavy consumption and consequently increased feed costs. This is especially true when grains other than corn are fed. By grinding the grain and mixing it with the supplement in proper proportion this can be avoided. Another method which permits the self-feeding of the supplement is that of replacing half the supplement with ground oats. Excessive consumption of the expensive protein feeds has been successfully prevented also by self-feeding the supplement and minerals together after mixing the two in the ratio of about 5 to 1. This latter method, however, generally is not to be recommended because of the difficulty of adjusting the proportions under different conditions so that there will be no excess consumption of either.

In dry-lot feeding, when alfalfa meal is fed mixed with the supplement in an amount to represent about 10 percent by weight of the ration as a whole, as is desirable, the consumption of the supplement when self-fed usually will not be greater than needed. This would mean a proportion of one part alfalfa to from one to two parts of the supplement.

15 W. L. Robison, Bul. 552, 1935.

Commercial mixed feeds and supplements. The Census of Manufactures[16] reports that the prepared animal feeds shipped in the United States in 1947 had a value totaling $2,215,044,000.

In 1948 farmers in the state of Indiana alone spent over 100 million dollars for one million tons of commercial feeding stuffs.[17] Approximately three-fourths of this was for mixed feeds, and one-fourth for the straight single protein by-products, including alfalfa meal, such as tankage, meat scraps, fish meal, soybean oil meal, linseed meal, cottonseed meal, middlings, and bran. Of the mixed feeds, hogmen were credited with the purchase of 163,000 tons at a cost, in round numbers, of 100 dollars per ton.

Compared with the farm-mixed supplements made up of single standard high-grade animal- and plant-protein feeds, the commercial mixed supplements, as a general rule, include in addition to these, numerous mineral and vitamin additions. The minerals include not only calcium, phosphorus, and iodized salt, but also iron and most of the so-called trace elements. The vitamins include, as a rule, A, D, and six or seven of those contained in the so-called B-complex group. Molasses also is an ingredient of most of them. Four of the most popular brands sold in Indiana had fiber contents ranging from 8 to 12 percent, which is not excessive.

Most of the popular brands of commercial mixed feeds now carry a protein content varying from 30 to 42 percent, and have been designed to supplement the farm grains. Most companies also put out a second type of feed which is designed to substitute for, rather than to supplement, the farm feed supply. These are "complete" and contain grains and mill by-products, in addition to the high-grade protein feeds, in such proportions that the amount of protein in the mixture is about 14 to 20 percent. These also generally are fortified with the minerals and vitamins known to be essential, or are suspected of having some value.

Suggested rules in the purchase of protein supplements. The hogman annually is confronted with the problem of deciding which is the cheapest and most efficient means of securing the protein supplements that are necessary to balance his home-grown feed supply. Observation of the following principles or general rules is suggested as a help in this connection:

1. The purchase of some protein-rich feeds is necessary on the hog

[16] U.S. Dept. of Commerce, Bureau of Census, 1949.
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MINERAL DEFICIENCY OF THE CEREAL GRAINS

Corn alone is lacking in bone-making material. Corn and the other cereal grains are not only deficient in the amount and quality of their proteins to meet the needs of the growing pig, but they are also seriously lacking in certain minerals, particularly calcium or lime, and common salt.

An experiment conducted by Burnett of the Nebraska Experiment Station in 1907 [18] shows the effect of feeding mineral-deficient rations on the growth and strength of bone of growing pigs. Beginning August 2, and continuing for 154 days, he fed 20 pigs in five groups of four each the rations shown in Table 59. The pigs averaged 62 pounds at the start. During the first 84 days, or for more than one-half of the experimental period, all lots were on alfalfa pasture; for the remainder of the time they were confined to dry lots. The alfalfa, being rich in vitamins and bone-making materials, had the effect here of protecting the pigs fed the mineral-deficient rations against the development of the more severe cases of malnutrition, such as rachitis and posterior paralysis. In Table 59 are shown the more important results from this study.

Table 59. The Effects of Mineral-deficient Rations on the Size and Strength of Bone

Rations Fed		*Average Weight of Green Bones in Grams* [a]	*Average Circumference of Bones in Millimeters*	*Average Thickness of Bone Wall in Millimeters*	*Percentage of Mineral Matter in Green Bone*	*Average Breaking Strength of Bones per 100 Lb. Live Weight of Pigs*
Corn meal	100%	1,097	73.0	2.8	25.4	325
Corn meal Shorts	75% 25%	1,044	69.9	2.9	27.8	396
Corn meal Skim milk	25% 75%	1,232	71.3	3.7	32.7	509
Corn meal Tankage	90% 10%	1,219	73.6	3.7	35.5	580
Corn meal Ground bone	90% 10%	1,196	71.6	4.1	37.2	681

[a] The above figures were obtained by averaging the data for the following bones of each pig: two femur, two tibia, two humerus, and two ulna and radius.

[18] E. A. Burnett, Bul. 107, 1908.

farm, but because of their cost, their use should be restricted to the minimum, consistent with production results.

2. Other factors being the same, those feeds should be preferred which furnish a unit of protein at the lowest cost.

3. Generally, the feeds which supply the protein in the most concentrated form are the most economical, since it permits a larger proportion of the ration to be made up of corn and other farm-grown feeds.

4. By the discriminating purchase of single standard high-protein feeds, and the use of prime alfalfa or other legume hay and green forage, the informed farmer can usually mix his own supplements cheaper than he can buy them ready-mixed.

5. As with brood sows, the mineral needs of growing and fattening pigs can, as a rule, be provided more economically and effectively in simple home-made mixtures than by purchasing them in commercial mixed feeds. Likewise, the essential vitamins can be supplied more economically in farm-grown feeds and animal or fish supplements.

6. In the purchase of commercial mixed supplements, attention should be given to the manufacturer's guarantee concerning its chemical analysis and the identity of the ingredients contained in the mixture, as stated on the state chemist's official tag. A high percentage of protein means a low proportion of carbohydrates, which the farm normally supplies in abundance, while a low fiber content ensures the absence of a "filler" or low-grade products of little or no feeding value.

7. Feeders should consult with their experiment station workers more generally than they do. They will be better advised on feeding problems by research men in the field of nutrition than by those whose main concern is to promote the sale of their own particular brand of feed.

Experiment stations have not undertaken systematic feeding trials to test the value of commercial mixed feeds. This is because of the great variety and also the feeling that the respective brands may not, as the result of price fluctuations in the products used in their manufacture, remain constant in composition and quality from year to year. A favorable experimental showing for a particular brand would give opportunity to the unscrupulous manufacturer to take advantage of the results by cheapening the feed subsequently, despite the necessity of complying with the state feed-control regulations.

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Although these pigs were confined to dry lots during the last 70 days only of the feeding period, several striking differences are apparent in the results. The breaking strength of the bones of the pigs fed skim milk, tankage, or ground bone, with corn, was from 56 to 109 percent greater than for the pigs fed corn alone. This greater strength was not due to larger apparent size, but to a thicker bone wall and a denser structure of the bone material. The difference in the percentage of mineral matter contained in the bones and the thickness of the bone wall was marked. Adding 25 percent of shorts to a corn ration had little effect on the strength or composition of the bone produced compared with corn alone because, like corn, this feed is very deficient in calcium or lime.

Fig. 37. Stiffness, lameness, rheumatism, crampiness, rachitis, or bone fractures may result when pigs are fed rations deficient in bone-building ingredients. At the left is a normal ham bone or femur; the shaft is strong and the wall dense and hard. At the right is a fractured femur of a pig fed a ration seriously deficient in calcium or lime, which resulted in the production of bone tissue of a soft and porous character *(Ohio Exp. Sta., Bul.* 395, 1926).

This experiment supplies positive evidence of the bone-building deficiency of corn. Chemical analyses have made it clear that this is due chiefly to its very low calcium or lime content. The practical effect of adding the tankage or skim milk was not only to supply needed proteins, but to furnish the calcium and other mineral elements which corn lacks so seriously. Other studies by Burnett and similar studies by Carlyle [19] and Forbes [20] have given results which confirm those reported here.

[19] W. J. Carlyle, Wis. Exp. Sta., Bul. 104, 1903.
[20] E. B. Forbes, Ohio Exp. Sta., Bul. 213 and 283.

Lime-deficient rations produce rachitis. Nutrition studies by Evans of the Animal Nutrition Institute, Cambridge University [21] furnish material which demonstrates the mineral poverty of the common cereal grains, particularly in calcium, and the relation of this deficiency to the development of rachitis in growing pigs. Under carefully controlled conditions he fed one group of weanling pigs on a ration composed of barley and corn, balanced with a mixture of animal and plant proteins and common salt, adequate in all respects except in its supply of lime or calcium. To another similar group he fed the same ration with a generous addition of ground limestone, which contained 85 percent calcium carbonate. The latter was fed mixed with the other feeds in an amount sufficient to make it 1½ percent of the ration. To make certain that the results would not be affected by other than the calcium factor the pigs were confined to concrete-floored pens, exposed to the sunlight, and fed cod-liver oil regularly to ensure an adequate supply of vitamins A and D.

The basal ration was made up in the proportions shown below:

Barley meal	44.5%
Maize (corn) meal	44.5%
Bean meal	3.8%
Blood meal	6.6%
Common salt	0.5%

The results were definite and striking. As the feeding period progressed the author observed that the pigs on the low-lime ration "showed obvious signs of malnutrition, being periodically 'off their feet,' with legs bending inward, and with a scurvy, dirty appearance." At the age of seven months these pigs averaged but 71 pounds in weight, some of them were losing weight, and all had gone "off their feet" and showed typical symptoms of rachitis. Chemical analyses made of the bones of representative pigs from the two groups at the close of the feeding period showed the pronounced difference of 12 percent in their ash content. The bones of the normal pigs were hard, while those from the rachitic pigs were soft and porous and could easily be scraped with a knife.

Posterior paralysis produced by calcium and vitamin-deficient rations. Extensive studies by Bohstedt and associates at the Ohio Experiment Station [22] of the causes of "stiffness" in pigs brought to light the important fact that posterior paralysis is often caused by nutri-

[21] R. E. Evans, *Jr. Agr. Sci.*, Vol. 20, Part 1, 1930.
[22] G. Bohstedt, W. L. Robison, R. M. Bethke, and B. H. Edgington, Bul. 395, 1926.

tionally deficient rations such as those composed of the cereal grains and their by-products. This was long suspected, but never clearly demonstrated experimentally. During the 4-year period commencing in 1921 he conducted eight series of feeding experiments involving the use of a total of 452 pigs. In each of seven series one lot of pigs was fed a basal ration composed of the following feeds:

Ground white corn	55 to 75%
Flour wheat middlings	9 to 25%
Linseed oil meal	10 to 20%
Common salt	0.5 to 1%

Other lots of similar pigs were fed the same ration with the addition of various minerals rich in calcium, and cod-liver oil. The pigs were confined to concrete-paved lots, 10 by 12 feet, six to seven in one group. The trials began soon after the pigs were weaned, at an average weight of 40 pounds, and covered periods for the individual experiments lasting from 5 to nearly 7 months, some in winter and some in summer.

The basal ration, containing white instead of yellow corn, and including only cereal by-products, was deficient in vitamin A, as well as in B-complex and other vitamins, and in lime or calcium. Vitamin D was also present in meager amounts, although access to the direct sunshine tended to counteract the effects of its absence. As one might expect, the feeding of such a ration for a protracted period proved disastrous. None of the pigs fed the basal ration in any of the series of tests grew vigorously; most of them had depraved appetites, rough coats, wrinkly skins, and were stunted. Toward the end of the feeding period the breathing generally became labored and many were stiff. There were eight or more cases of posterior paralysis. Generally, more than one-half the pigs died before the termination of the feeding period, the immediate cause being pneumonia. Systematic examination of the bones in the autopsy studies showed seven cases of fractured vertebrae, usually in the loin region, six fractured femurs, many "beaded ribs," abnormalities all suggestive of rachitis and associated maladies.

With reference to the immediate cause of the cases of posterior paralysis studied, the authors made the following important observation:

> An immediate cause of posterior paralysis was found to be fractured vertebrae in the lumbar-sacral region of the spinal column. The cases of posterior paralysis were associated with poorly calcified bones, due to a ration low in cer-

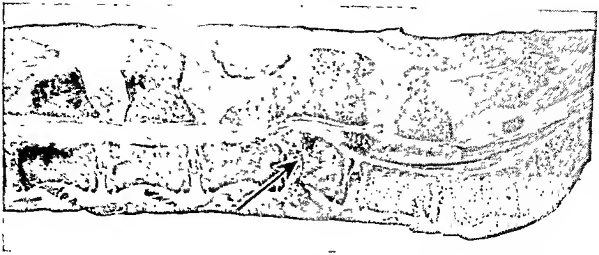

Fig. 38. A vertical-longitudinal section through the spinal column showing a crushing fracture of the fifth lumbar vertebra, at arrow point, caused by a ration deficient in bone-building material. The spinal cord was pinched and posterior paralysis resulted. Beginning at the weight of 30 pounds, this pig had been fed the calcium-deficient ration of white corn, wheat middlings, linseed meal, and common salt for a period of 22 weeks when death occurred *(Ohio Exp. Sta., Bul.* 395, 1926).

tain minerals and vitamins. It appeared as if the weakly constructed lumbar vertebrae were unable to withstand any sudden and severe contraction of the powerful back muscles, as caused by slipping on the floor or through fright. One or another vertebra would thus be subject to a crushing fracture, bulging inward and pinching the spinal cord, thus acting as a nerve block for the rear extremities. The pigs that were posteriorly paralyzed on the experimental rations showed no kidney worms on autopsy.

Because of the fact that the basal ration was deficient in two important particulars, namely in vitamins and calcium, it was not possible to assign exact causes for all the specific effects observed. That the deficiency in calcium was one of the chief nutritional factors responsible for the bone troubles, however, was shown by the fact that when ground limestone was added to the basal ration in an amount sufficient to make it 2 percent of the ration, the pigs grew much better and their bone development was practically normal. The lack of vitamins in this ration, however, resulted in the death of a number of individuals during the latter end of the experimental period. Supplying cod-liver oil alone, which is rich both in vitamin A and D, with the basal ration in an amount equal to 1 percent of the grain, did not prevent fractures of the bones unless calcium salt was fed with it. When both calcium and cod-liver oil were fed, the pigs made rapid and uniform growth and were undisturbed by bone fractures or respiratory troubles.

Common salt is required for health and growth. Animals that live primarily on vegetable feeds display a natural craving for salt. Even when the ration of the pig is supplemented with animal-protein feeds, he will eat a considerable quantity when offered it free-choice. Generally, it has been taken for granted that all classes of hogs should be given salt in addition to their regular rations. Until fairly recently, however, there was lacking a practical demonstration of its importance in the diet of the pig.

Experiments carried on by Vestal of the Indiana Station [23] supplies information of this kind. In four dry-lot trials a basal ration of shelled corn, a plant supplement composed of 90 percent soybean oil meal and 10 percent alfalfa leaf meal, and a mineral mixture made up of equal parts pulverized limestone and steamed bone meal, was self-fed, free-choice, to two lots of pigs. One lot received in addition loose salt in a self-feeder; the second lot got none. The pigs of each group numbered from 7 to 15 in the different years, and were fed for periods averaging 83 days from an average initial weight of 64 pounds. A summary of the results obtained is shown in Table 60.

Table 60. Salt versus No Salt for Pigs in the Dry Lot
(Average 4 Experiments)

Rations	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required for 1 Cwt. Gain*		*Cost per 1 Cwt. Gain*
	lb.	*lb.*		*lb.*	
Sh. corn + supplement + mineral mix. NO SALT	4.98	0.89	Corn	444	$16.46
			Supplement	105	
			Minerals	10	
			Total	559	
Sh. corn + supplement + mineral mix. + SALT	6.14	1.64	Corn	305	$11.17
			Supplement	67	
			Minerals	0.69	
			Salt	1.70	
			Total	374.39	

The effect of the added salt in each of the four trials was striking. Compared with those which got no salt, the salt-fed pigs, on the average, ate 23 percent more feed and gained at nearly double the rate on

[23] C. M. Vestal, Mimeo. No. 18, 1945; Mimeo. No. 20, 1946; Mimeo. No. 23, 1947; and Mimeo. No. 28, 1947.

33 percent less feed. The difference of $5.29 in the cost of 100 pounds of gain gave to 1 pound of salt the value of $3.11!

The pigs without salt showed early signs of restlessness, poor appetites, and an interest in foreign substances as food. Apparently in an

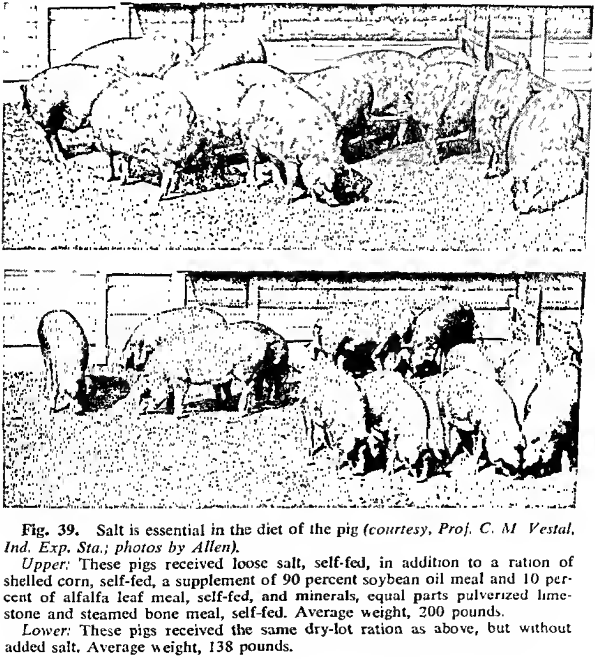

Fig. 39. Salt is essential in the diet of the pig *(courtesy, Prof. C. M Vestal, Ind. Exp. Sta.; photos by Allen).*

Upper: These pigs received loose salt, self-fed, in addition to a ration of shelled corn, self-fed, a supplement of 90 percent soybean oil meal and 10 percent of alfalfa leaf meal, self-fed, and minerals, equal parts pulverized limestone and steamed bone meal, self-fed. Average weight, 200 pounds.

Lower: These pigs received the same dry-lot ration as above, but without added salt. Average weight, 138 pounds.

effort to satisfy the craving for salt, they consumed daily approximately eight times as much of the mineral mixture as those that had salt available. In the lots receiving salt, the amount of it eaten represented 0.45 percent of the ration, which, incidentally, was more than double the amount consumed of the limestone—bone-meal mixture

In 1947 Vestal compared two lots under the same conditions as

those in the above trials, in which the protein supplement in the basal ration was composed of equal parts meat and bone scraps and soybean oil meal alone. As would be expected, because of the higher salt content of the meat and bone scraps, the difference in the rate and cost of gains between those receiving salt and those not receiving it was less marked than that shown in the summarized results above. In this trial those having free access to loose salt in a self-feeder gained 1.70 pounds daily, while those without it gained 1.59 pounds daily. The feed required to produce 100 pounds of gain was 373 and 408 pounds, respectively. The amount of salt consumed in Lot I represented 0.27 percent of the ration.

Salt feeding not so necessary with animal supplements. Aubel of the Kansas Station [24] in two dry-lot experiments failed to secure any significant response from the addition of salt, free-choice, to a ration composed of (a) shelled corn, tankage, alfalfa hay, self-fed, free-choice, or (b) a similar ration self-fed, free-choice, in which the protein supplement was 40 percent tankage, 40 percent soybean oil meal, 10 percent linseed oil meal, and 10 percent alfalfa meal. That these pigs had a craving for salt, however, was shown by their consumption in the first experiment of an amount equal to 0.53 percent of the ration, and in the second of 0.77 percent of the ration.

Pigs on pasture apparently require salt. In another Indiana trial a comparison was made with three lots of pigs on alfalfa pasture, the protein supplement being soybean oil meal. Lot I received no minerals and no salt; Lot II received the limestone—bone-meal mineral mixture but no salt; Lot III was given both the mineral mixture and salt, self-fed, free-choice. The rate of gain of the three groups was 1.02, 1.23, and 1.58 pounds daily, respectively; the total dry feed required to produce 100 pounds of gain was 454, 439, and 349 pounds, respectively. The salt consumed in Lot III amounted to 0.74 percent of the ration.

Some general observations on salt feeding. In the Indiana experiments the amount of salt consumed when fed free-choice, in addition to a mineral mixture composed of equal parts of pulverized limestone and steamed bone meal, self-fed, exceeded in every instance the amount of the mineral mixture eaten. The average for four dry-lot and one pasture experiments showed more than double the consumption of salt than of the limestone—bone-meal mixture. Data furnished by the experiments conducted by Willman and Morrison of the Cornell

[24] C. E. Aubel, Mimeo. Rpts., 1947 and 1948.

New York Station [25] make it possible also to observe the amount of salt consumed when supplied, free-choice, in addition to the mixture composed of two parts ground limestone, two parts steamed bone meal, and one part salt, self-fed. All lots were fed in dry-lot well-balanced rations, containing both animal and plant supplements, and about 5 percent alfalfa meal. In 116 lots, an average of 1 pound of the extra salt supplied free-choice was consumed for each 1½ pounds of the mixture.

Assuming that the amount of salt eaten by the pig when offered it free-choice is related to his physiological needs, the above observations furnish good grounds for the suggestion that the simple mineral mixture of 40 percent ground limestone, 40 percent of steamed bone meal, and 20 percent of salt would be improved by increasing the proportion of salt. At least, it is a basis for recommending that, when fed in the above proportions, additional salt be provided in a second compartment of the mineral feeder.

"Salt poisoning" uncommon. In his review of the literature on salt tolerance and salt poisoning, Ellis of the U.S. Department of Agriculture [26] reports the results of an experiment at the Rowett Research Institute in Scotland in which feeding as much as 3.3 percent of salt in the ration to pigs weighing 60 to 190 pounds failed to produce any symptoms of ill health. In trials conducted at the Beltsville Research Center, he recites their inability to produce toxic effects with any consistency. In one series of tests, pairs of pigs were fed diets containing 0, 1, 2, 4, 8, and 12 percent of salt, respectively. Increasing the level of salt beyond 2 percent was found to reduce feed intake and gains. However, those receiving 12 percent ate sufficient feed to give them a salt consumption approximately of half a pound per day. One pig of the pair receiving the 8 percent level showed evidence of salt poisoning on the eighty-sixth day. He refused feed for two days and, "when forced to move he walked with a hesitant, nervous motion, frothed at the mouth, and champed his teeth." Five days after removal he had recovered 10 pounds in weight and appeared normal, except for blindness.

In the Indiana experiments, Vestal attempted to produce salt poisoning by giving the salt-starved pigs access to loose salt, meat brine instead of drinking water, and plain salt water containing the same concentration of salt as the brine, without success. Some of the

[25] John P. Willman and F. B. Morrison, Bul. 836. 1947.
[26] N. R. Ellis, *1942 Year Book of Agriculture*, p. 803.

pigs offered loose salt were made sick, but after vomiting, no further symptoms were observed. One pig, after 88 days without added salt, consumed 9 ounces in 48 hours, another ate 6½ ounces, while six others consumed individually only 1 to 1½ ounces during this period.

Charcoal of doubtful value. Willman and Morrison of the Cornell New York Station [27] made extensive studies of the value of charcoal when fed at the rates of 1 and 3 percent of otherwise satisfactory rations to growing and fattening pigs in the dry lot. The results of six trials showed that the average daily gain for the pigs which received no charcoal was 1.29 pounds, for those receiving 1 percent it was 1.25 pounds, and for the pigs getting 3 percent it was 1.27 pounds. The amount of feed required for 100 pounds of gain in the three respective lots was 388, 386, and 397 pounds. Statistical analysis showed that any differences were too small to be significant, and hence the conclusion that the charcoal was neither harmful nor beneficial.

Trace minerals. The experimental information which we have indicates that the only minerals which need concern the feeder, with but few exceptions, are those contained in otherwise good rations and/or in simple mixtures, such as limestone, bone meal, or like materials, and salt. Iodized salt should, of course, be fed instead of straight salt in the goiterous and semigoiterous areas. The iron supply is of special importance for nursing pigs, as has been indicated.

There are areas of the country, however, where because of natural soil peculiarities or where through constant cropping the fertility has became seriously depleted, the use of certain of the trace elements, such as iodine, iron, copper, cobalt, zinc, manganese, or magnesium, may be needed. Recent studies suggest that these areas are more extensive than was formerly supposed. In five experiments carried out by Willman and Noland at the Cornell New York Station [28] it was shown that, for weanling pigs on concrete floors fed to market weight, the addition of the trace minerals iron, copper, cobalt, and zinc to the all-plant rations of ground yellow corn, soybean oil meal, 10 percent of ground alfalfa hay, and iodized salt with a supplement of calcium and phosphorus increased the rate of gain from 1.03 pounds daily to 1.23 pounds, and reduced the amount of feed required to produce one hundredweight of gain by 20 pounds.

Longwell and Severson of the North Dakota Station,[29] as the result

[27] John P. Willman and F. B. Morrison, Bul. 836, 1947.
[28] John P. Willman and Paul R. Noland, Reprint, *Farm Research*, Vol. XV, No. 4, Oct., 1949.
[29] J. H. Longwell, and Al Severson, Bimonthly Bul., Vol. VI, No. 4, 1944.

of one experiment, reported unfavorably on the use of complex mineral mixtures. They secured somewhat faster and cheaper gains with the simple mixture of 40 percent steamed bone meal, 40 percent ground limestone, and 20 percent salt than with any one of three widely sold complex commercial mixtures.

Commercial mineral feeds. The numerous brands of mineral feeds which are offered on the market and the tonnage sold, which represented an estimated cost in one state of 1,861,300 dollars in 1948, suggest their importance to the feeder.

These mineral feeds contain not only calcium, phosphorus, iodized salt, and most of the trace minerals, but generally also various appetizers, tonics, laxatives, worm-expellers, charcoal, and sulphur. Summing up their extensive review of the literature, with particular reference to the use of medicated mixed minerals, Mitchell and McClure [30] have this to say:

> Healthy animals do not need such treatment, while sick animals need treatments suited to the particular disorders from which they are suffering. Such medicated mixtures cannot effectively combat internal parasites or constipation; to do so they would have to be given in such doses as to interfere seriously with the appetite and vigor of the animal. Nor can their use in any way diminish the need of sanitary measures in livestock management. Furthermore, the more medicines and tonics that the mineral mixtures contain the less of the essential calcium and phosphorous compounds that will be found in them. The practice of including in commercial mineral mixtures many more components than are necessary for the proper supplementing of farm rations increases the cost of the mixture generally far beyond its inherent value as a supplement in animal feeding. To those farmers who believe that commercial minerals have served them well in their business and who are steady users of them, it may be suggested that the active ingredients in these mixtures which are doing all the good work are the limestone, or the bone meal, and the salt contained in them.

VITAMINS

For vigorous growth and development, as well as for efficient reproduction and lactation, vitamins are necessary. Especially is this the case with young pigs and those which are more or less closely confined during the winter. Those of particular importance to the feeder are vitamins A, D, and those belonging to the B-complex group, including the so-called animal protein factor (APF). In addition to these, there are nutritionally important vitamin-like factors of unknown

[30] H. H. Mitchell and F. J. McClure, *National Research Council*, Bul. No. 99, p. 79, 1937.

identity, one of which is referred to as the "grass-juice factor," and others which are contained in liver extract.

White corn and other cereals deficient in vitamin A. Vitamin A is important to the feeder because of the near-complete absence of

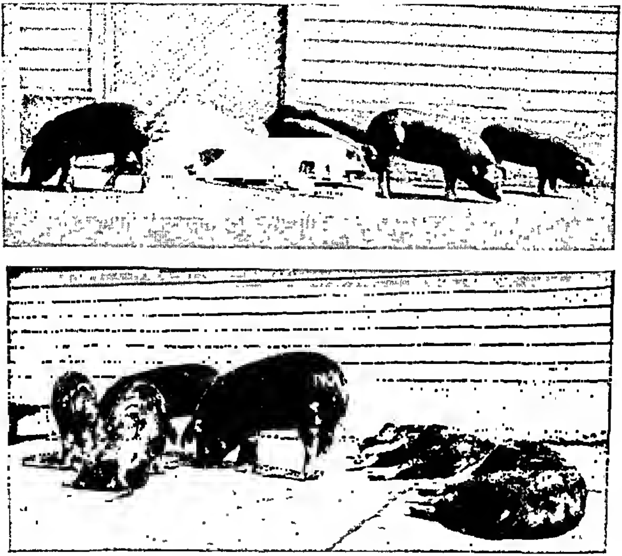

Fig. 40. Vitamin A is essential in a growing ration (*Kans. Exp. Sta., Tech. Bul.* 23).

Upper: The pigs in one of the lots of the Kansas experiment at the start of vitamin-A–deficient feeding. The ration was composed of white corn, tankage, and bone ash.

Lower: The same pigs 265 days later. The two pigs standing, like the prostrate ones, developed advanced nerve disorder but had been partially cured by giving them cod-liver oil.

carotene, the plant form of the vitamin, in all the cereal grains and by-products except yellow corn (see page 173). The experimental studies of Hughes and associates of the Kansas Station,[31] which were

[31] J. S. Hughes, C. E. Aubel, and H. F. Lienhart, Tech. Bul. 23, 1928.

begun in 1921 and continued through seven years, demonstrated the importance of this vitamin in the diet of the pig and its deficiency in white corn. In five trials they fed a ration of white corn, tankage, and bone ash to pigs from weaning to 11 to 15 months of age. The pigs, numbered four to six in each group, had the run of small cement-paved lots.

The final result was the death of all pigs. The first death occurred after seven months on this ration, and all had died which had not been killed for examination by 15 months. The authors stated that the pigs were normal and made uniformly good gains during the first four or five months, and that the appetites were good up to the last stages of disorders. The pathological symptoms in the order of their appearance were enumerated as follows: restlessness, mean disposition, humped posture when standing and walking, soreness, stiffness, incoordination affecting the hind quarters, inability to get up on their feet, severe spasms, and death. They found that the addition of good alfalfa hay to the ration in an amount to represent 10 percent afforded complete protection.

In 1921 Morrison and coworkers of the Wisconsin Station [32] demonstrated that yellow corn was superior to white corn. In a number of dry-lot experiments, starting when the pigs weighed 50 to 65 pounds and continuing to market weight, the pigs fed yellow corn gained faster and more economically. In two of the trials in which skim milk was fed as the protein supplement, 13 of the 20 pigs died before the experiment closed. The symptoms of vitamin A starvation were the same as those described in the Kansas studies. When yellow instead of white corn was fed, or when cod-liver oil was added to the white-corn ration, partial or complete recovery resulted. Also, it was found that by adding 5 percent of chopped alfalfa hay to the ration white corn gave as good results as yellow corn.

Similar studies, comparing white with yellow corn, were made at the Illinois and West Virginia Stations with like results. Dunlap of the Animal Nutrition Research Institute, Cambridge University,[33] found that when pigs were fed from weaning to market weights on the commonly used ration of barley meal, middlings, and fish meal, or cereals, soya-bean meal (soybean oil meal), and minerals, symptoms of paralysis due to vitamin A deficiency developed when the pigs reached a weight of 150 pounds, or about 15 weeks after weaning. Complete

[32] F. B. Morrison, G. Bohstedt, and J. M. Fargo, Buls. 323 and 339.
[33] G. Dunlap, *Jr. Agr. Sci.*, Vol. 24, Part 3, 1934.

recovery, even of those pigs which had become prostrate, was accomplished in 5 weeks by feeding cod-liver oil, or crystalline carotene, along with the ration on which the disease developed.

It is probable that other food factors, in addition to vitamin A, were involved in the results of some of these experiments. Although none of the experimental rations was complete, it is at the same time apparent that vitamin A was the factor chiefly responsible for the disastrous results noted.

Farm supply of vitamin A adequate. Despite the practical absence of carotene or vitamin A value in any of the concentrates except yellow corn, the hogman has available an ample home-grown supply in fresh green forage and high-quality hays. Feeding good-quality alfalfa hay or meal in an amount to represent 5 percent of the ration by weight will ensure a sufficient supply of this vitamin for short dry-lot periods, especially if the pigs have good reserves as the result of previous forage feeding. Recent experiments, however, have shown that 10 percent of alfalfa, or even 15 percent, is better, particularly when consideration is given to the need for some of the other vitamins. So far as vitamin A is concerned, pigs on forage normally will have sufficient reserves to tide them over short periods of drought during the late summer without the addition of a vitamin supplement. Good practice would suggest, however, the feeding of 5 to 10 percent of alfalfa meal in the ration during extended drought periods.

Vitamin D. This vitamin is a food factor of considerable importance to the hogman. Its presence in the ration is necessary to guarantee the efficient functioning of the minerals supplied in the ration. The most common effect of its absence in swine feeding is to interfere with the deposition of lime or calcium salts in the growth of bone. Its chief function, in other words, is to help protect the animal against those nutritional disturbances which terminate in rachitis. For this reason it is known as the antirachitic vitamin.

We have just observed how a deficiency of calcium may cause rachitis even when the supply of vitamin D is ample (see page 211). Vitamin D is to be regarded, therefore, as one factor only in the disturbance, the other being the supply of minerals, particularly calcium and phosphorus. When the supply of calcium is adequate and in the correct ratio with phosphorus, and the other salts are sufficient, the effect of a deficiency of vitamin D will not so soon be apparent as when the supply of calcium is limited. Likewise, the optimum amount of calcium necessary to give maximum results in growth, or to protect

against rachitis and allied troubles, is influenced by the amount of vitamin D which is present. Vitamin D and calcium, in other words, bear a complementary relationship one to the other. It must be remembered, however, that each is indispensable and that neither the mineral salts nor the vitamin factor can wholly, or in large part, replace the other (see page 170).

Experiments with small laboratory animals, chickens, and pigs indicate that the cereal grains as well as both the animal and plant protein supplements contain very meager amounts of vitamin D. Although fresh green forage is rich in the substance which produces the vitamins when exposed to sunlight after cutting, the uncut plant contains practically none. Cod-, halibut-, and shark-liver oils are rich in it, while the oils of the soybean and flaxseed contain little. The vitamin D factor in feeds has been increased by exposing them for short periods to direct sunlight. By subjecting milk to the ultraviolet rays of sunlight its antirachitic potency has been increased as much as eight or ten times.

Sunlight a source of vitamin D. The part played by sunlight in good mineral nutrition should be explained at this point. A rachitic condition shown by stiffness, crampiness, or rheumatism is known to be more common among fall than spring pigs. This is due in part to the difference in the strength of the sun's rays in winter and summer. When the rays of sunshine strike the animal body the cumulative effect is to bring about a chemical reaction in the skin which results in the formation of the vitamin D substance. Only the short, or ultraviolet, rays are capable of bringing about this result. It is this type of light which is artificially produced by the quartz mercury-vapor lamp. When sunlight passes through ordinary window glass, the short rays are deflected and its potency largely destroyed. To receive measurable benefits the animal must be exposed to the direct rays. The place of sunshine in animal nutrition is due to its power to create or activate the vitamin D substance of the animal body. It serves, therefore, as an indirect source of vitamin D.

Vitamin D and sunshine protect pigs against rachitis. Experiments conducted by Shaw of the University of Saskatchewan [34] demonstrate effectively the practical value of sunlight as an indirect source of vitamin D for growing pigs. During each of 3 years he fed four groups of pigs, eight in each, a ration composed of oats, recleaned wheat screenings, wheat middlings, buttermilk, and a mineral mixture

[34] A. M. Shaw, *Sci. Agr.*, Vol. XI, No. 1, 1930.

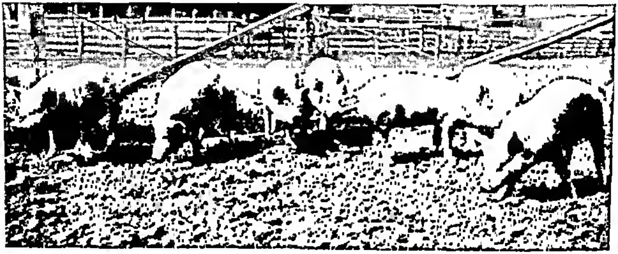

Fig. 41. Sunshine is a source of vitamin D *(courtesy, Prof. A. M. Shaw, University of Saskatchewan).*

Upper: Pigs badly affected with rachitis induced by a lack of direct sunshine and a ration deficient in vitamin D, as they appeared at the close of a 120-day feeding experiment.

Lower: The same pigs as shown in the upper picture after 2 months of spring sunshine and open-yard feeding on the same ration. The potency of direct sunshine as a factor in the prevention and cure of rachitis is here demonstrated.

rich in lime and common salt. Each group had an individual house and a 10- by 18-foot exercise yard. In one lot the yard was open and the pigs had daily access to sunlight. In the other three groups the yards were covered and the fences made tight so that all direct sunlight was excluded. One of these lots received light through a south-exposed window containing 8 square feet of ordinary glass. In the third lot the window contained Vitaglass, a glass of special manufacture which is of a character that permits the passage of most of the short or ultraviolet rays without distortion or diffusion. Lot four had no window and hence little if any light.

The results of the second trial, summarized in Table 61, represent fairly the general results of the study. In this particular test the pigs were started on test December 16, 1928, at an average weight of 42 pounds, and continued on test for a period of 120 days.

In interpreting these results it is necessary to remember that the ration fed these pigs was rich in calcium and contained little if any vitamin D. Vitamin A probably was lacking also, but since the pigs in the sunlight group were normal it cannot be regarded as a factor in these results.

Table 61. Showing the Effects of Sunlight on Growing Pigs

Conditions	*Number of Pigs*	*Total Average Gain per Pig*	*Number of Normal Pigs*	*Number Affected with Rachitis*	*Number Complete Cripples*	*Percentage Normal Pigs*
		lb.				
1. Open yard	8	100	8	0	0	100
2. Window glass	8	81	0	5	3 [a]	0
3. Vitaglass	8	74	0	5	3	0
4. Dark	8	81	1	5	2 [b]	12½

[a] One died before close of experiment.
[b] Both died before close of experiment.

The evidence presented in the table is rather convincing in showing the importance of sunlight as a factor in nutrition when pigs are fed a ration deficient in the antirachitic vitamin. That the ration was deficient in vitamin D is shown by the fact that practically none of the pigs which were denied sunlight were able to make normal gains and practically all showed unmistakable signs of rachitis before the close of the trial. On the other hand, pigs having access to the open lot made fair gains and were normal. The author also reported that 150 stock pigs were fed the same ration at the same time in a lot adjacent to the experimental pigs and none developed any signs of rachitis. That sunlight after passing through ordinary window glass is not effective in bringing about improvement was indicated by the performance of Lot 2. The special glass used in the experiment did not give better results than ordinary glass, although the area of glass allowed in both lots may have been too small to permit of a differentiation in the results.

The potency of direct sunlight as an agent in the cure of rachitis, even in the latitude of Saskatoon, was shown by the subsequent be-

havior of the pigs in Lots 2, 3, and 4 after the close of the experiment proper when the covering of the yards had been removed on about April 15. In describing what followed this change the author incidentally gives us a vivid picture showing the abnormal condition of the pigs at the close of the experiment.

Immediately the pigs took advantage of the light and remained outside the pen, stretched out on their sides most of the time. The skin soon commenced to take on a ruddy hue (they were Yorkshire pigs) and, in a comparatively few days, an improvement in their physical condition was noticeable. At first, some of the pigs were unable to use their hind quarters at all, and dragged themselves about with great difficulty. Others walked on their knees while others had enlarged joints or bent legs. All of them, however, slowly recovered the use of their limbs and gradually began to thrive. Those least affected soon began to gain rapidly in weight and even some of those pigs that were listed as complete cripples at the conclusion of the experiment eventually recovered sufficiently to be marketed.

As a result of these three series of experiments the author made the additional observation that young pigs show the effects of restricted light much more quickly than do older pigs, and that pigs which have developed normally up to 3 or 4 months of age seem to be able subsequently to withstand comparatively long periods of restricted light without injury.

This experiment showed the value of sunlight for pigs fed a ration deficient in vitamin D but rich in calcium. Studies by Maynard, Goldberg, and Miller of Cornell University [35] demonstrated that sunlight has special value when pigs are fed a ration deficient in both calcium and vitamin D. On such a ration, containing less than 0.1 percent of calcium, these authors found that the pigs without sunshine developed stiffness in four months, while seven of the eight pigs receiving the same ration with the sunlight showed no signs of this trouble. Although the bones of the pigs exposed to sunlight were hardly normal, chemical analysis showed them to contain considerably more ash than did the bones of the no-sunlight group. The sunlight, in other words, made it possible for the pigs to use more completely or efficiently the very meager allowance of calcium provided by the ration. Loeffel and assistants of the Nebraska Station [36] found that direct sunlight prevented rachitis in pigs fed a ration deficient in vitamin D, while another group of similar pigs fed the same ration developed severe rachitis when exposure to direct sunlight was denied them. The ration

[35] L. A. Maynard, S. A. Goldberg, and R. C. Miller, *Jr. Biol. Chem.*, Vol. 65, 1925.
[36] W. J. Loeffel, Res. Bul. 58, 1931.

fed contained 0.2 percent of calcium. Studies by Sinclair of the University of Alberta [37] showed that winter sunlight exerts physiological benefits and results in faster and cheaper gains and bone of higher ash content even when the ration fed the pigs is already fairly high in its vitamin D content, as well as rich in calcium.

Johnson and Palmer of the Minnesota Station [38] found that rachitis in pigs was cured by exposure to sunshine 45 minutes per day for 2 weeks. Also, it was found that when fall pigs were given an outside runway during the winter and self-fed high-grade sun-cured alfalfa in addition to an otherwise good ration containing ample minerals, they did not become rachitic when the consumption of the hay represented 5.05 percent of the ration. They also found, however, that when an inferior grade of hay was fed under the same conditions some of the pigs developed symptoms of the disease. More vitamin D and/or sunshine were required to cure rachitis than to prevent it.

In the earlier trials by the same investigators [39] it was shown that pigs with dark pigmentation stored less vitamin D in their bodies on exposure to sunshine than white pigs. Experimental studies at the Ohio and Wisconsin Stations also indicated that vitamin D deficiency symptoms generally appeared first among the black and red pigs.

Bethke and coworkers of the Ohio Station [40] concluded after five trials that the forms of vitamin D supplied by cod-liver oil and irradiated yeast were equally effective in the prevention or cure of rachitis. They found that the minimum practical amount required by pigs confined to a darkened barn and supplied with a ration containing ample minerals was 90 International Units per pound of feed.

It would appear from all this that the supply of vitamin D presents no serious problem to the practical hogman, even during the winter in the upper Corn Belt. However, it does point rather definitely to the necessity, especially in the northern latitudes, of feeding as part of the ration from 5 to 10 percent of the finest quality sun-cured legume hay available and of including in the diet of the pigs an ample supply of calcium and phosphorus in the ratio of about 1½ to 1

Vitamins of the B-complex group important. Recent studies of the nutrition of the pig have brought to light two important facts: one, that rations which are satisfactory for growing fattening pigs from

about 75 pounds up to market weight often prove deficient for younger pigs; and two, that these deficiencies generally involve the supply of some of the water-soluble or B-complex vitamins and/or other unknown food factors. Results of these studies also suggest that the diet of the mother during gestation and lactation may have an important bearing on the susceptibility of her pigs later to certain nutritional deficiencies. The attempt will be made here to summarize briefly the results of those studies which appear to affect good feeding practices.

Studies by Fairbanks and coworkers of the Illinois Station [41] showed that a ration balanced with animal-protein supplements, such as corn, wheat-flour middlings, expeller soybean oil meal, with 8 percent of tankage and 3.5 percent of fish meal, fortified cod-liver oil, and minerals, when fed to weanling pigs in the dry lot was markedly improved by the addition of the six better known B vitamins, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, and choline, or of alfalfa meal sufficient to represent 10 percent of the ration. However, McMillen and associates of the Michigan Station [42] concluded that a similar ration, containing 12 percent meat scraps and either 10 percent of dehydrated alfalfa meal or 5 percent of sun-cured alfalfa, was deficient in pantothenic acid, nicotinic acid (niacin), and riboflavin for confined weanling pigs weighing 24 pounds at the start of the test.

Experimental studies by Dyer and others of the Illinois Station [43] showed that for weanling pigs fed in the dry lot a ration composed of 63.5 percent of ground yellow corn, 34 percent of expeller soybean oil meal, 2 percent of a complex mineral mixture, and 0.5 percent of fortified cod-liver oil was déficient in riboflavin and pantothenic acid, and was borderline in its content of choline for maximum growth. The pigs made only one-half normal gains, had rough hair coats, bad skins, exhibited locomotor difficulties, and were subject to scouring throughout the test of 65 days. Similar results had been observed by Keith and associates of the Pennsylvania Station [44] on a similar ration containing 4 percent of sun-cured alfalfa.

Based on the results of a large number of experiments with growing and fattening pigs in the dry lot, Robison of the Ohio Station [45] con-

[41] B. W. Fairbanks, J. L. Krider, and W. E. Carroll, *Jr. An. Sci.*, Vol. 4, No. 4, 1945.
[42] W. N. McMillen, R. W. Luecke, and F. Thorp Jr., *Jr. An. Sci.*, Vol. 8, No. 4, 1949.
[43] J. A. Dyer, J. L. Krider, and W. E. Carroll, *Jr. An. Sci.*, Vol. 8, No. 4, 1949.
[44] T. B. Keith, R. C. Miller, W. T. S. Thorp, and M. A. McCarty, *Jr. An. Sci.*, Vol. 1, No. 2, 1942.
[45] W. L. Robison, *Farm and Home Research*, Bul. 246, 1947.

cluded that a ration of yellow corn, soybean oil meal, and minerals, and containing 4 to 5 percent of ground, sun-cured alfalfa of good quality was deficient in one or more respects for pigs in the dry lot. The results were the same when oats replaced the corn, or when a mixture of linseed and cottonseed meal was fed in place of the soybean oil meal, although each was of some benefit.

He found that "when 10 to 12 percent of high quality alfalfa meal was used, or when water was added and yeast was grown in the wet feed, or when dried brewer's yeast, condensed fish solubles, dried distillers' solubles, fish meal, or meat scraps was included in the ration the pigs remained healthier, grew normally, and made more rapid gains and greater gains per unit of feed consumed than pigs on the untreated or unaugmented ration."

From these and other similar studies at the other stations it is concluded that when such rations have added to them high-quality alfalfa meal in an amount to represent 10 to 12 percent of the ration that the supply of the better known water-soluble or B-complex vitamins will be adequate except possibly for very young pigs. The results, however, will not be optimum unless some animal or fish-protein supplements, or other carriers of vitamin B12 and other factors, such as are contained in the animal protein factor (APF), are added.

The animal-protein factor (APF). Feeders generally have found that rations balanced with a protein supplement of animal origin, such as any of the milk by-products, tankage, meat and bone scraps, fish meal, condensed fish solubles, or liver meal, gave better results in growth and reproduction than rations balanced with supplements of plant origin. Scientists have determined that this superior supplementing efficiency is due chiefly to the presence in the animal products of certain vitamin-like factors to which the name animal-protein factor (APF) was first given. This factor, it is important to understand, is not a protein, but is a combination of factors associated in small amounts with animal proteins but not with plant proteins.

This so-called factor (APF) is a product which results from bacterial fermentation processes employed by pharmaceutical and chemical laboratories in the production of antibiotics. These laboratories are the original sources of the APF concentrates now on the market. They may be obtained direct from the manufacturers, or indirectly as a premix from feed retailers, or by the purchase of commercial mixed supplements which contain them.[46]

[46] Damon Catron, Ia. Exp. Sta., *Iowa Swine Breeders' Directory*, 1950–1951.

It is now quite definitely established after several years of research at the U.S.D.A. Research Center at Beltsville, Md., and a number of the state experiment stations and commercial laboratories of the country, that APF is a complex made up of several different ingredients. These are (1) the growth-promoting vitamin B12, also known as the antipernicious anemia factor, (2) certain antibiotic residues in crude form resulting from the production of crystalline aureomycin, streptomycin, penicillin, terramycin, etc., and (3) probably also other factors not yet definitely known.

That this APF concentrate contains these factors in a much more concentrated or potent form than are found in the usual animal-protein supplements, and that it also contains some ingredients or factors not contained in most of these supplements, is indicated by the experimental studies which have been made.

The growth-stimulating and health-promoting properties of this so-called animal-protein factor (APF) have now been experimentally demonstrated by many carefully controlled practical pig-feeding tests. These would include the studies at the Iowa, Indiana, Illinois, Wisconsin, Minnesota, Cornell, Michigan, Ohio, Missouri, and Florida Stations, and the Hormel Institute, particularly.

General summary of APF (with aureomycin) experiments.

1. These feeding experiments have uniformly shown, using growing and fattening pigs fed a basal all-plant ration containing everything known to be necessary in the diet, that the addition of an APF concentrate resulted in a rather marked increase in feed consumption and rate of gain, and some reduction in the amount of feed required to produce a unit of gain. In many instances the differences were striking. These were the results whether the pigs were confined to concrete-paved lots or were on pasture, although, as a rule, there was less difference in the pasture experiments.

2. When an all-plant ration with added APF concentrate was compared with a similar ration balanced with packing-house and/or fish proteins, also, or a combination of these with plant proteins, for growing and fattening pigs either in the dry lot or on pasture, the APF-supplemented ration proved superior, particularly in the rate of gain produced.

3. The experimental studies also showed that when the APF concentrate was added to a presumably complete ration balanced wholly with animal supplements, the rate of gain was significantly increased,

and the amount of feed required for a unit of gain was slightly reduced.

4. Another important fact which emerged rather clearly from a number of these studies was that APF contains a factor or factors which prevent and control the ordinary type of scours, and are especially potent in helping to rejuvenate unthrifty or runty pigs. In a number of the experimental reports the observation also was made that the APF-fed pigs tended to fatten at earlier weights than those fed the check rations.

To what extent these results can be attributed to vitamin B12, the antibiotic residues, or to other factors contained in the APF concentrate, it is impossible to judge from these experiments.

Vitamin B12 a growth-promoting factor. This is one of the newer vitamins, first produced in pure form from liver extract in 1948. It is believed to be the same as the antipernicious anemia factor used in human medicine. It is synthesized, along with other B vitamins, by certain microorganisms of the paunch of ruminants, which accounts for its presence in cow manure.

It is now fairly well established as the result of extensive research that vitamin B12 is required in the diet of the pig, and that some of the growth-stimulating properties of APF concentrates are the result of its presence in these products.

The exact quantitative requirements of the pig for this vitamin have not been determined. Extremely minute amounts of the pure product, however, are required. For example, 10 micrograms of the pure B12 to each pound of the ration have been shown to be sufficient to give a significant growth response. This amount is equivalent to one-fiftieth of a gram to each ton of feed. There are about 28.4 grams in 1 ounce.

Carpenter of the Hormel Institute reported that vitamin B12 when fed to young pigs, had no effect on the incidence of diarrhea.

Antibiotics promote growth and control scours. Such terms as aureomycin, streptomycin, penicillin, terramycin, and bacitracin are now more or less familiar to hogmen. Hundreds of these antibiotics have been produced, and those mentioned above have been subjected to considerable study in experimental swine rations.

In the production of antibiotic drugs by the pharmaceutical laboratories, which involves carefully controlled biofermentations by certain microorganisms, residues are produced which contain the antibiotic factor. This residue, as a dried mash, is the form in which the

antibiotics have been fed in most of the experimental studies that have been made, in an amount to equal from 0.25 to 0.50 percent of the ration. Catron and associates of the Iowa Station [47] showed that pure crystal aureomycin when fed in an amount as small as 5 milligrams per pound of feed produced a significant growth response when added to a well-fortified all-plant corn-soybean ration.

The many experimental studies to date would seem to support the following general observations concerning the value of antibiotics in pig rations:

Several of these antibiotics have been shown to possess significant growth-stimulating properties when fed as supplements to well-fortified rations to pigs, either when confined to concrete-paved lots or on pasture. More response was shown on some rations than on others.

Aueromycin is especially effective in stimulating gains; streptomycin, terramycin, and penicillin have been equally effective in a number of tests. Even when fed as a supplement to a ration balanced with meat and bone scraps, either in the dry lot or on pasture, antibiotics increase significantly the rate of gain.

Perhaps the greatest value of these antibiotics to the practical feeder, however, will be found in their capacity to control scours in young pigs. In numerous trials during the past 2 years aureomycin, streptomycin, terramycin, and penicillin have been effective both in the prevention and cure of this common ailment. Unthrifty runty pigs after a few weeks' treatment appear rejuvenated; scouring disappears, the appetite improves, gains pick up, skin health improves, and the hair coat takes on a glossy appearance.

In what manner these antibiotics function is a matter for speculation. So far as their effect in the control of scours is concerned, however, the most reasonable theory is that they inhibit the growth of or destroy the harmful microrganisms in the intestinal tract, thus promoting the growth of the desirable organisms, thereby bringing about a more normal and healthful intestinal environment. It seems reasonable to assume also that the growth-stimulating effects of antibiotics may partly be the result of this improvement in the bacterial flora of the digestive tract, as well as the result of the presence of the specific growth factor.

The term "animal-protein factor" officially abolished. In order to provide a nomenclature which defines the separate nutritional

[47] D. V. Catron, V. C. Speer, H. M. Maddock, and R. L. Vohs, *Jr. An. Sci. Abst.*, Vol. 9, No. 4, 1950.

factors contained in the so-called animal-protein factor (APF), in line with the findings of recent research, the Association of American Feed Control Officials at their last annual meeting (January, 1951) established the following definitions and regulations with respect to labeling and selling of the products:

Vitamin B12 supplement is a feeding material used for its vitamin B activity. It shall contain a minimum of vitamin B12 activity of 1.5 milligrams per pound. The term shall not be applied to products for which there are accepted names and definitions.

Antibiotic feed supplement is a feeding material used for its antibiotic activity. It shall contain a single antibiotic or combination of antibiotics having growth-promoting properties. The name and amount of each antibiotic shall be declared on the label. It shall contain a minimum of 1 gram per pound of antibiotics. The label shall bear the legend "for feeding use only." Directions for use shall provide for incorporating not more than 50 grams of antibiotic per ton of finished feed.

The executive committee also adopted the following resolution: "Resolved, that if a feeding material is represented to be a combined vitamin B12 and antibiotic feed supplement, it shall meet the potency standards and other label and informational requirements established for each component."

THIOURACIL AND THYROPROTEIN

One of the newer phases of nutrition has involved a study of the relation of the hormone thyroxine to the growth and fattening processes in swine. This hormone is the active agent of the internal secretions of the thyroid gland, its chief function being to regulate the rate of the metabolic processes of the body. An overactive thyroid tends to accelerate the pulse rate, elevate the body temperature, increase muscular tension, and to stimulate bodily activity. Subnormal activity of the gland has the opposite effect, inhibits the production of thyroxine, reduces the metabolic rate, and results in sluggishness and inactivity.

Since the development by scientists of products which excite superactivity of the gland, such as thyroprotein (iodinated casein), and others which depress it, such as thiouracil and thiourea, studies have been made to determine the possible value of these drugs when added to growing and fattening rations. All together, some seven or more Stations [48] have reported results of experimental studies, most of which have been more or less of a preliminary character.

[48] Missouri, New Jersey, Michigan, Texas, Cornell, Illinois, and Indiana.

Effect of thiouracil in the fattening ration. The results obtained in the feeding of thiouracil during relatively short growing and fattening periods have not been uniform; in a number of instances they have been directly contradictory. A systematic study of the experiments, however, reveals the following points of interest:

1. In a majority of the comparisons—four out of six—the feeding of thiouracil as 0.1 to 0.25 percent of the ration, fed according to appetite to partly grown pigs weighing from 125 to over 200 pounds at the start for periods of 25 to 63 days, resulted in reducing the rate of gain slightly to seriously as compared with the controls. In two of the six reports the gains were slightly greater on the ration containing the thiouracil.

2. In a majority of the reports—four out of six—the pigs receiving thiouracil under the same conditions as above made slightly to significantly greater gains per unit of feed; in two, the feed required for a unit of gain was increased.

3. When the basal ration was limited to the same feed intake as the test ration, those receiving thiouracil gained faster and required less feed for a unit of gain.

4. Better results, as a rule, were secured when the thiouracil was fed at a level of 0.1 to 0.15 percent of the ration than when on a 0.2 to 0.25 percent level. The Illinois workers concluded that 0.15 percent of the ration was most nearly optimum. At Cornell, 0.1 percent proved to be better, or less harmful, than 0.2 percent.

5. The feeding of thiouracil tended to result in greater economy in the use of feed, due probably to a slowing down of the metabolic rate and a lethargic state of inactivity in the pig which it induces. Such a condition facilitates the fattening process. On the other hand, its effect on the palatability of the ration resulted in reduced feed consumption and generally slower gains.

6. Thiouracil was fed to weanling pigs starting soon after weaning at the New Jersey and Indiana Stations. In both experiments the results proved disastrous. The Indiana workers reported a markedly reduced feed consumption and growth rate, and the development of a severe skin affliction. In the New Jersey trial the control pigs gained 1.67 pounds daily while those that received thiouracil gained 0.57 pound.

Thyroprotein for growing pigs. This drug has the opposite effect on the metabolic rate to that produced by thiouracil. Because of its tendency to speed up all the vital activities, research workers have rea-

soned that its use in pig rations might promote faster gains and earlier market finish.

A limited amount of experimental work on this question has been reported by the New Jersey, Indiana, and Michigan Stations. At New Jersey, pigs were hand-fed from the weanling stage until a weight of 125 pounds was reached on full rations containing from 0.075 to 4.0 grams of thyroprotein daily for each hundredweight of pig. When fed at rates of 0.075 to 0.225 gram there was no significant effect on either the rate or cost of gains. When higher levels, 0.5 to 4.0 grams, were fed, however, the rate of gain was depressed and the feed required for a unit of gain significantly increased.

In each of two series of experiments at the Indiana Station favorable results were obtained. In these trials 53- and 42-pound pigs were full-fed for periods of 84 and 119 days. When the thyroprotein was fed at the level of 2 grams per 100 pounds of feed, no significant effect on the rate or cost of gains was observed. When fed at levels of 4, 6, or 8 grams, however, all treated pigs made significantly faster gains and required less feed for a unit of gain than those fed the basal ration alone. It was observed in these studies that the accelerating effect of the thyroprotein on rate of gain was exerted chiefly after a weight of about 125 pounds had been reached.

In two experiments at the Michigan Station, Berkshire, Duroc, and Yorkshire pigs fed from weaning for a period of 112 days gained considerably faster on less feed, compared with the controls, when given thyroprotein at the level of 2.8 grams per 100 pounds of feed. In one trial, however, Chester White pigs gave no response when fed the same dosage. When thyroprotein was fed at the level of 5.6 grams per 100 pounds of feed stiffness was observed in the pigs when they reached a weight of about 140 pounds, which disappeared when they were changed to a level of 2.8 grams. The thyroprotein-fed pigs consistently showed finer, smoother hair coats and less body scurf than the controls.

As a general conclusion, it may be said that there is little evidence thus far that these products will soon become commercially important to the practical feeder.

IX Forage Crops

It is a matter of common observation that pigs do better when given access to green forage than when confined to a dry lot. Although the pig's digestive capacity is limited compared with that of the horse, cow, or sheep, and strictly speaking he is not a grass-eating animal, he nevertheless is able to consume an amount which may contribute materially to his support.

Superior quality of nutrients in forage. The use of forage is an important factor in producing pork economically in this country, however, not so much because of the amount which is consumed, but rather because of its superior quality. Dry-lot rations often are lacking in sufficient proteins of the right sort, and frequently are deficient in minerals, especially calcium and common salt. Probably the most important contribution made by green forage to better nutrition, however, is the result of its rich supply of vitamins. In addition to the nutritional benefits, forage crops provide the conditions which simplify greatly the problems of disease prevention and parasite control.

Grazing capacity of pigs. There is little exact information concerning the amount of forage a pig will eat under different feeding conditions. Investigations by Woodman and Norman of the Institute of Animal Nutrition, Cambridge,[1] showed that pigs weighing 150 to 190 pounds and receiving 68 percent of a full meal ration ate 4.4 pounds of cut grass daily. The grass was cut with a lawn mower and fed fresh. Eighty-five percent of the dry matter of the meal, and 60 to 62 percent of the grass, was digested. The conclusion was drawn that 6.3 pounds of fresh young pasture was equivalent to 1 pound of meal. Their studies also showed that sows nursing pigs and receiving a full ration of meal (14 pounds daily) will eat in addition 5 pounds of fresh young grass daily. They quote Todd to the effect that a sow on limited rations will not consume more than 15 pounds daily. Stewart[2] con-

[1] H. E. Woodman, and D. B. Norman, *Jr. Agr. Sci.*, Vol. 24, Part I, 1934.
[2] W. A. Stewart, *Pig Keeping*, Min. of Agr. and Fish., Bul. 32, 1931.

cluded from observations that a sow will consume 20 pounds of green forage daily, and a 6-months-old pig 12 to 14 pounds. The presumption is that little if any grain or meal was fed in these cases. Woodman and Evans of the School of Agriculture, Cambridge,[3] found that when pigs were limited to a meal ration of 2½ pounds a day, from the weight of 50 to 150 pounds, the consumption of young cut grass when fed according to appetite was as follows: at the weight of 50 pounds, the average daily consumption of grass was 0.24 pound; at 100 pounds, 4.9 pounds; and at 150 pounds, 8.6 pounds of grass.

American records show that the mature sow in thin condition after weaning her pigs will about maintain her weight on good bluegrass alone, and on good legume forage will gain ½ pound or more daily until fair condition has been recovered. Snyder of the North Platte, Nebraska, Station,[4] in two trials found that for periods of 63 and 95 days respectively after weaning their pigs the sows on good alfalfa pasture without grain made an average daily gain of 0.43 pound the first year and 0.53 pound the second. These sows were mature and thin in condition when the trials began. In another trial, 14 thin yearling hogs that had been grown on alfalfa and a light grain ration gained at the rate of 0.50 pound daily from June to August on alfalfa pasture without concentrates.

THE VALUE OF FORAGE CROPS

Dry-lot versus forage feeding. As a result of the extensive studies that have been made at the experiment stations of the country, it is now generally taken for granted that forage feeding of spring pigs during the summer results in faster and cheaper gains and more profit as compared with the dry-lot method. For an example of this there are given in Table 62 the summarized results for 25 selected experiments. Only those experiments are included here in which full rations were fed and an adequate supply of protein was provided in both rations. The ration most commonly fed was corn and tankage. In all cases the trials began soon after the pigs were weaned and continued until practically market weights were reached, which represented an average period of 106 days. Rape was the forage grazed in six of the trials, red clover in four, alfalfa in ten, timothy in three, a mixture of Canadian field peas, rape, and oats in one, and soybeans in one.

[3] H. E. Woodman and R. E. Evans, *Jr. Agr. Sci.*, Vol. 33, p. 201, 1943.
[4] W. P. Snyder, Bul. 99, 1907.

Table 62. Dry-lot versus Forage Feeding
(Average 25 Experiments)

	Average Daily Gain	*Average Concentrates to Produce 100 Pounds Gain*	*Concentrates Saved per Acre of Forage*	*Amount of Pork Accredited 1 Acre of Forage*
	lb.	lb.	lb.	lb.
Dry lot	1.106	404	...	...
Forage	1.355	356	1172	329

Although the pigs in the dry lot were fed rations which were fairly well balanced according to the standards at that time, those having access to forage in addition made an extra gain of ¼ pound daily, on the average; in some cases the difference in rate of gain was greater than this and in others it was less. In no case did those in the dry lot gain as rapidly as those on forage. At the end of the feeding period the forage-fed pigs were on the average 27 pounds heavier.

The concentrates fed the pigs on forage went much farther also in producing gains than those fed in the dry lot. For the production of 100 pounds of gain, the green feed consumed by the forage pigs had the effect of saving 48 pounds of concentrates. The average number of pigs grazed to the acre in these tests was 17. From this and the rate and feed cost of the gains in the two lots, it was calculated that an acre of forage had the value of 1172 pounds of concentrates or the equivalent value of 329 pounds of pork. The money value of an acre of forage, based on the saving of feed required to produce a unit of gain as compared with dry-lot feeding, may therefore be figured on the basis either of the cost of the feed or the value of the pork. In Table 63 are given the money values which the average acre of forage had in these experiments as determined by both methods and with varying prices.

Table 63. Average Value of an Acre of Forage for Growing and Fattening Pigs

When 1 lb. of pork (live wt.) is worth:	6¢	7¢	8¢	9¢	10¢	12¢	14¢
An acre of forage is worth:	$19.74	$23.03	$26.32	$29.61	$32.90	$39.48	$46.06
When 1 lb. of concentrates costs:	1½¢	1¾¢	2¢	2½¢	2¾¢	3¢	3½¢
An acre of forage is worth:	$17.58	$20.51	$23.44	$29.30	$32.23	$35.16	$41.02

The above table illustrates the usual method of expressing the money value of an acre of forage when grazed by pigs. It should be understood, however, that these values are determined solely by the saving effected in the cost of the gains and do not include any credit due for the faster gains and earlier market finish, as well as other benefits. In addition to the forage eaten, the legumes furnished usually one cutting of hay. The above figures, therefore, underrate rather than overrate the value which an acre of forage had in these tests.

In applying the results of such experiments, it is well to remember that the benefits to be derived from a given area of forage varies widely according to the character of the ration fed as well as the quality of the forage. The better the ration, the less will be the benefits derived from the forage; and the poorer the ration, the greater will be the benefits. With the recent advances in knowledge, it is now possible to construct a dry-lot ration so complete in food essentials that the forage is of little benefit except for the improved sanitary conditions which it provides. On a ration of corn alone, on the other hand, its value is double or treble that which it had in the above experiments. Likewise, the money value of an acre of forage is greater when the pigs are fed a half-grain ration than when on a full ration, although the same number of pigs will require a larger forage area.

Summary of benefits from forage feeding. The following general observations on the benefits of forage feeding are suggested by the experimental studies that have just been reviewed together with those discussed in previous chapters.

1. Forage crops have their greatest value on the hog farm when grazed by the breeding classes. For brood sows during the gestation and lactation periods, the benefits are expressed in stronger pigs, fewer death losses, heavier pigs at weaning time, and fewer breeding failures subsequently (see page 48). Due to its residual effects, gilts that have been on forage during early growth are able to survive a considerable period of deficit dry-lot feeding without serious injury. The fertility of boars can be maintained only when they are provided with those food constituents which are abundantly supplied in green forage.

2. Growing pigs on forage make faster gains than those confined to the dry lot, other conditions being the same. It has been observed also that they are capable of sustaining a rapid rate of gain for a longer period of time. With fairly well-balanced rations and full feeding, the rate of gain was increased 22 percent in the experiments summarized in Table 62. On corn alone, forage will increase the rate of gain often by more than 100 percent. On the other hand, with nearly ideal ra-

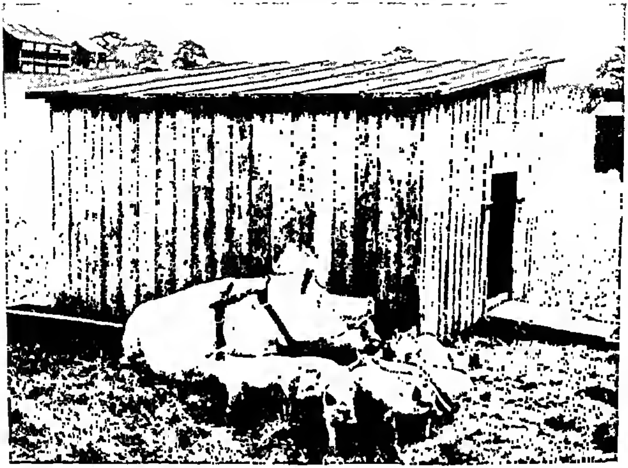

Fig. 42. Tethering the nursing sows is a common practice in England and other European countries. It conserves pasture, prevents mixing of sows and litters, and helps to promote good sanitation practices *(courtesy, E. B. Lomax and R. Silcock & Sons, Liverpool, England; photo by W. S. Crawford Ltd., London).*

tions, the rate may be but little more than for those fed in the dry lot. Forage-fed pigs gain faster because their food demands are more completely satisfied, their capacity for handling feed is increased, and the conditions under which they are maintained are more healthful.

3. Pigs which have been on forage during the summer do better subsequently when placed in the dry lot than those which have not had the advantage of green feed. The beneficial effects of the forage, in other words, are not confined to the forage period alone, but are noticeably maintained during the succeeding weeks of dry-lot feeding. This is another reason why the figures given in Table 63 do not represent the full value of these crops. This desirable residual effect is the result, no doubt, of the more vigorous state of health brought about by better nourishment and sanitary conditions and of the larger capacity resulting from the consumption of the bulky succulent feed.

4. When corn or other grain is very high or unobtainable, a forage

crop makes it possible, with the minimum of grain, to maintain thrift and fair gains during the summer until the next grain crop is harvested. Without such a crop the farmer frequently is forced to sacrifice his pig crop by marketing at very immature weights or of carrying them through under conditions which are injurious to health and fatal to profits. The value of an acre of forage in such a situation, which is not uncommon, is very much greater than that which is shown by the usual method of calculation.

5. Forage crops help to reduce the cost of producing pork. As a rule, even with full and fairly well-balanced rations, pigs on forage will make their gains on from 10 to 12 percent less concentrates than are required by pigs confined to the dry lot. When the ration fed is not well balanced, the grain saved by the forage is much greater, amounting frequently to as much as 50 percent. With good forage crops, this saving alone is usually more than sufficient to pay all the costs involved in their production. The higher the price of grain, the more important does this saving become.

6. Another important advantage, especially in the Corn Belt, results from the fact that forage reduces by 30 to 40 percent the amount of commercial protein supplements needed to balance the home-grown grains. This is because the tender growth of these crops, particularly the legumes, contains most of the food constituents which the grains lack, such as protein, minerals, and vitamins. The new growth of these crops, as well as that of bluegrass and the cereal forages like oats, rye, and barley, are much richer in these growth-promoting qualities than the same crops at maturity. Provision of forage crops means that the hog farm is made more independent of outside sources of feed supplies.

7. Access to forage ensures that the droppings will be left where the land is certain to receive full benefit from the fertility contained. Contrasted with the results of dry-lot feeding where too often the droppings are allowed to accumulate and waste away, this system effects a large and increasingly important saving. More than 85 percent of the fertility contained in the feed is returned in the manure. With present prices of commercial fertilizers, the fertility contained in the droppings of a well-fed pig during the summer would have a value of $3.00 to $5.00.

8. Finally, and most important, forage crops mean improved sanitary conditions. If for no other reason, all so-called permanent hog lots

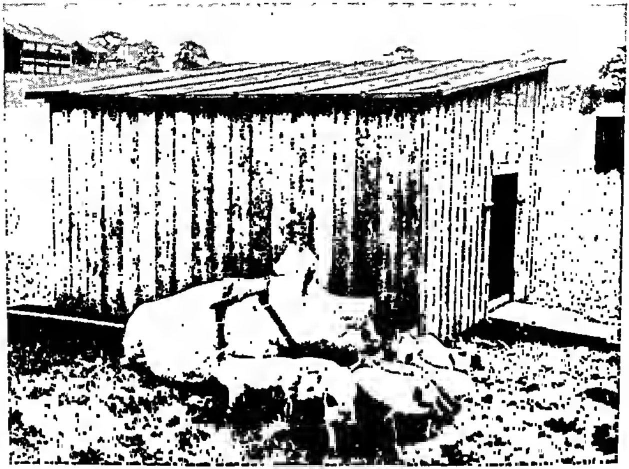

Fig. 42. Tethering the nursing sows is a common practice in England and other European countries. It conserves pasture, prevents mixing of sows and litters, and helps to promote good sanitation practices *(courtesy, E. B. Lomax and R. Silcock & Sons, Liverpool, England; photo by W. S. Crawford Ltd., London).*

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4. When corn or other grain is very high or unobtainable, a forage

crop makes it possible, with the minimum of grain, to maintain thrift and fair gains during the summer until the next grain crop is harvested. Without such a crop the farmer frequently is forced to sacrifice his pig crop by marketing at very immature weights or of carrying them through under conditions which are injurious to health and fatal to profits. The value of an acre of forage in such a situation, which is not uncommon, is very much greater than that which is shown by the usual method of calculation.

5. Forage crops help to reduce the cost of producing pork. As a rule, even with full and fairly well-balanced rations, pigs on forage will make their gains on from 10 to 12 percent less concentrates than are required by pigs confined to the dry lot. When the ration fed is not well balanced, the grain saved by the forage is much greater, amounting frequently to as much as 50 percent. With good forage crops, this saving alone is usually more than sufficient to pay all the costs involved in their production. The higher the price of grain, the more important does this saving become.

6. Another important advantage, especially in the Corn Belt, results from the fact that forage reduces by 30 to 40 percent the amount of commercial protein supplements needed to balance the home-grown grains. This is because the tender growth of these crops, particularly the legumes, contains most of the food constituents which the grains lack, such as protein, minerals, and vitamins. The new growth of these crops, as well as that of bluegrass and the cereal forages like oats, rye, and barley, are much richer in these growth-promoting qualities than the same crops at maturity. Provision of forage crops means that the hog farm is made more independent of outside sources of feed supplies.

7. Access to forage ensures that the droppings will be left where the land is certain to receive full benefit from the fertility contained. Contrasted with the results of dry-lot feeding where too often the droppings are allowed to accumulate and waste away, this system effects a large and increasingly important saving. More than 85 percent of the fertility contained in the feed is returned in the manure. With present prices of commercial fertilizers, the fertility contained in the droppings of a well-fed pig during the summer would have a value of $3.00 to $5.00.

8. Finally, and most important, forage crops mean improved sanitary conditions. If for no other reason, all so-called permanent hog lots

should be plowed up frequently and sown to crops. Not only will such lots produce a heavy yield of forage, but the complete aeration of the soil and the action of the direct rays of the sun will ensure the death of parasites and disease germs more effectively and at less cost than can be accomplished by any other practical method. Pigs on forage in contact with clean earth are more thrifty and vigorous than those confined to dry lots. One reason why pigs on forage display such capacity for rapid gains is because of this thrift. For pigs intended for the breeding herd, this thrift represents insurance against breeding failures and subsequent losses.

CHOOSING A FORAGE CROP

There is no best single forage, or succession of forage crops, for all farms and all seasons. Differences in climate, rainfall, and soil make it obvious that a crop well adapted to the South or West might prove a failure in the North or East. Normal variations in temperature and rainfall from year to year result also in wide differences in quality and value of any particular crop grown on the same soil in different years. The value of a crop in any year is conditioned on the favorableness of the season for that particular crop. Furthermore, differences in organization and system of cropping are responsible for the use of crops on some farms which would not be best where other systems of management are followed. For these reasons the choice of a forage is limited to those adapted to the climate, soil, and type of farm organization.

Essentials of an ideal forage. Kennedy and associates of the Iowa Station [5] enumerated the characteristics which are essential in a good forage by naming the following: (1) adaptability to the local soil and climate; (2) palatability; (3) heavy yield of digestible matter which is comparatively high in protein and ash (minerals); (4) narrow nutritive ratio, *i.e.*, not wider than 1 to 5, and better still if as narrow as 1 to 2; (5) succulence; (6) afford pasture for a long grazing season; (7) ability to withstand tramping and grazing; (8) permanency; (9) reasonable cost and ease of seeding; (10) capability of furnishing quick pasturage any time during the growing season; and (11) leguminous characteristic. In addition to a high content of protein and minerals, the importance of a rich supply of vitamins should be mentioned, which is in direct proportion to the immaturity, greenness, and leafiness of the plant.

[5] W. J. Kennedy, J. M. Evvard, H. H. Kildee, and E. T. Robbins, Bul. 136, 1913.

Composition of forage crops. As shown in Table 64 [6] forage crops of a maturity suitable for grazing are high in their content of water, but the dry matter which they contain is relatively rich in protein and calcium. In addition, they are rich sources of vitamin A and of those belonging to the B-complex group. These are the nutrients chiefly responsible for the thrift-promoting qualities of green feed, and their supplementing efficiency in balancing the home-grown concentrates.

The legume forages are generally regarded as more valuable than those belonging to the grass family. The reason for this is indicated when the composition of the two classes is compared. The figures in the table show that the dry matter of the legumes contains on the average 21 percent of protein, and that of the nonlegumes, 16.8 percent. In these same plants, also, the calcium content of the legumes represents 1.3 percent of the dry matter, and of the nonlegumes, 0.45 percent. The calcium-phosphorus ratio for the legumes is 3.26 to 1, and for the nonlegumes 1 to 1.

Table 64. Composition of Forage Crops

Crop	*Water*	*Protein*	*Carbohydrates* Nitrogen-free Extract	*Carbohydrates* Crude Fiber	*Fat*	*Calcium*	*Phosphorus*
Alfalfa, immature	79.4	5.2	8.0	3.8	0.7	0.28	0.09
Alfalfa, in bloom	77.2	3.2	9.4	7.8	0.6	0.39	0.07
Red clover, immature	81.2	5.0	7.3	3.0	0.8	0.27	0.10
Red clover, in bloom	70.8	4.4	13.5	8.1	1.1	0.44	0.07
Alsike clover, immature	81.2	4.9	7.8	3.1	0.6	0.26	0.09
Crimson clover, immature	80.9	3.1	8.4	5.2	0.7	0.28	0.04
Sweet clover, immature	75.3	5.3	9.8	6.7	0.7	0.26	0.07
White clover, immature	82.0	4.9	7.3	3.1	0.6	0.23	0.09
Lespedeza, immature	74.1	4.6	12.3	5.8	0.8	0.34	0.11
Rape	85.7	2.4	7.1	2.2	0.6	...	...
Bluegrass, K., immature	70.5	5.0	13.3	7.5	1.2	0.15	0.13
Timothy, immature	74.9	4.1	12.4	5.4	0.9	0.12	0.11
Barley, immature	83.4	2.8	8.0	3.6	0.7	0.06	0.07
Oats, immature	72.0	2.7	14.9	7.4	0.9	0.08	0.08
Rye, immature	80.8	4.5	7.9	3.4	1.1	0.10	0.10
Wheat, immature	82.3	3.8	7.9	3.0	0.9	0.07	0.10

[6] N. R. Ellis, W. R. Kauffman, and C. O. Miller, *U.S. Year Book of Agriculture*, p. 1065, 1939.

Chemical analysis also has revealed that the protein, calcium, and vitamin content of the leaf is much greater than of the stalk. As the forage grows and develops, the proportions of these nutrients in the dry matter decline. Not only is the younger growth better suited to the food demands of the pig, but it also is eaten in larger amounts due to its palatability and more tender character. The younger the pig, the more limited is his ability to use forage in the more advanced stages of growth. It may be regarded as a fortunate fact that the quality and composition of forages, in the physical and chemical changes which they undergo in growth, correspond in general with the needs and capacity of the pig to use them during the progressive stages of his development.

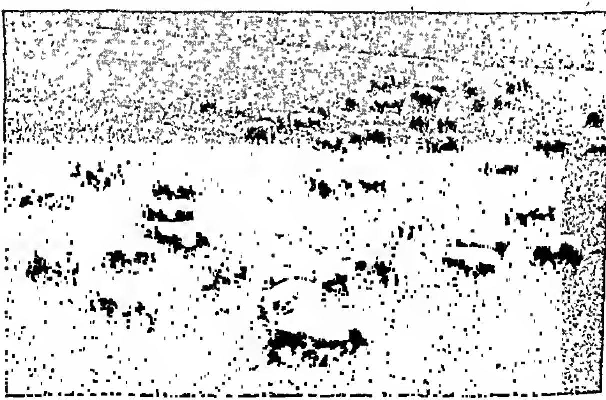


Fig. 43. Common red clover is a fixture in Corn Belt rotation systems and is one of the best forage crops for pigs (*photo by Allen*).

MEDIUM RED CLOVER

Common red clover is one of the most valuable and widely used forage crops for hogs. In the Corn Belt especially it is a fixture in the rotation system practiced on the best farms. In the South it is grown often as a winter annual. Being a legume it not only improves the soil by its nitrogen-gathering property, but its abundant supply of protein and lime, as well as vitamins, makes it particularly valuable as a forage for young pigs. Its richness in muscle- and bone-building foods ensures better results with straight corn feeding than can be obtained,

as a rule, from the nonlegumes. In a favorable season and when carefully handled an acre of red clover will supply grazing for 10 to 20 pigs from June to frost. The practice of cutting the first growth for hay and using the second for forage is often followed on farms where late pigs are produced. As an ally to corn in pork production this clover is without a peer.

Red clover does not thrive in high temperatures and does not stand drought as successfully as alfalfa or rape. Neither does it supply succulence in as uniform amounts throughout the summer months as does alfalfa. On some soils it is difficult to secure a "catch," it requires seeding every two years, and is subject to winter killing especially after overstocking. For best results pigs should not be turned in before the clover has attained a growth of at least 8 inches.

More specific information relative to the value of this crop in comparison with other forages is to be found by a study of the results of feeding trials conducted at the experiment stations. The more important recent studies are summarized in the following pages.

Clover versus alfalfa. These two premier forages have been compared in nine experimental feeding trials at the Iowa, Indiana, and Illinois Stations. In each trial the pigs used were of spring farrow, averaging in weight from 35 to 68 pounds when the experiments began. Full grain rations were fed in all but three cases; in these a half-ration was fed in two cases and in the other three-fourths of a full ration was given. In all but one of the experiments a small proportion of tankage was fed to supplement the corn. The results are shown in Table 65.

Table 65. Clover versus Alfalfa
(Average 9 Experiments)

Forage	*Average Number Pigs per Acre*	*Average Length of Tests*	*Average Daily Gain*	*Concentrates Eaten for Each 100 Pounds Gain*
		days	lb.	lb
Clover	15	113	1.290	352
Alfalfa	15	113	1.303	344

Although the rate of gain was practically the same, the pigs on alfalfa made their gains on somewhat less feed. Also the alfalfa plots produced the heavier cuttings of hay and furnished during the summer a more uniform supply of succulence, particularly when the season was dry.

Clover versus rape. These two forage crops have been compared in seven feeding experiments at the Iowa, Illinois, Wisconsin, and Indiana Stations the summarized results of which appear in Table 66. In each trial the pigs on clover were fed the same grain ration as those on rape. Pigs of spring farrow were used and, except in the Wisconsin trials, were confined to measured areas of forage. The experiments covered periods ranging from 60 to 141 days.

Table 66. Clover versus Rape
(Average 7 Experiments)

Forage	*Average Number Pigs per Acre*	*Average Length of Tests*	*Average Daily Gain*	*Concentrates Eaten for Each 100 Pounds Gain*
		days	lb.	lb.
Clover	19	97	1.305	359
Rape	18	97	1.167	349

In five of the seven experiments the pigs on clover made the faster gains, while the pigs on rape gained faster in two. In each trial, on the other hand, the pigs getting rape required less concentrates for the production of a given gain. In some of the experiments a small cutting of hay was taken from the clover lot. The carrying capacity of these two crops when grown on good soil appears to be about the same.

LADINO CLOVER

This fast-growing perennial legume, which spreads by creeping stems that take root at the joints, is the largest of the three varieties of white clover. The seed originally came to this country from northern Italy and was first successfully grown in the irrigated valleys of the West. It is successfully grown on the better soils of the New England states and is rapidly gaining favor in the Corn Belt as a forage of great promise. The growth is fine and leafy in character, it is highly nutritious and extremely palatable. It starts growth fairly early in the spring and continues to furnish grazing until late in the season. It recovers quickly after being grazed down. Because of its leafy character, it is difficult, by itself, to cure for hay. The root system is shallow and it does not stand extreme drought well. For thick, heavy production a fertile, well-drained soil is necessary.

Ladino versus alfalfa. The relative merits of these two legumes when used as forage for growing-fattening pigs were studied by Vestal

Fig. 44. Experimental pigs on ladino clover. This giant variety of white clover when grown on good soil has proved superior to alfalfa *(Leaflet* 226, *Ind. Exp. Sta.).*

and Mott of the Indiana Station [7] in experiments conducted in 1948 and 1949. The pigs, 15 and 18 to the lot, were fed from a starting weight of 47 pounds for periods of 84 and 90 days, respectively, in the two series. The forages were compared in two systems of feeding: in one with a protein supplement, in the other without a protein supplement. The basal ration consisted of shelled corn, self-fed, and a simple mineral mixture and salt, self-fed. The protein supplement was equal parts soybean oil meal and meat and bone scraps, self-fed. Lots receiving the supplement had 0.8 acre of forage; those without it 1.2 acres. The results, averaged for the two years, are summarized in Table 67.

Table 67. Ladino Clover Compared with Alfalfa
(Average 4 Experiments)

Rations	*Forage*	*Number Pigs Grazed per Acre*	*Average Daily Gain*	*Concentrates to Produce 100 Pounds Gain*
			lb.	lb
Basal + P. supplement	Alfalfa	20	1.60	Corn. 301 Sup. 37
Basal + P. supplement	Ladino	20	1 70	Corn. 297 Sup. 26
Basal only	Alfalfa	16	1.37	Corn. 334
Basal only	Ladino	16	1.51	Corn. 321

[7] C. M. Vestal and G. O. Mott, A.H. Mimeos. Nos. 35 and 43, 1948 and 1949

In both series of trials, in which there were a total of 66 pigs on each treatment, the pigs on ladino, both with and without supplement, consistently outgained those on alfalfa. And, what is also most significant, they ate 30 percent less protein supplement for a unit of gain. These results furnish strong testimony of the palatability, composition, and yield potentialities of this relatively new forage when grown on good soil.

Ladino compared with orchard grass. In an experiment conducted at the Pennsylvania Station in the summer of 1946, Gobble and associates [8] compared ladino and orchard grass as forages for pigs during a 108-day feeding period, the pigs weighing about 50 pounds at the start. Pigs in both lots were self-fed free-choice ground shelled corn, a protein supplement consisting of equal parts low-grade tankage and soybean oil meal, and a simple mineral mixture of limestone and salt. There were 19 pigs on an acre of ladino, and 20 pigs on about the same area of orchard grass.

The pigs on ladino made an average gain of 1.17 pounds daily at a feed cost of 346 pounds of concentrates for each 100 pounds of gain; those on the orchard grass gained at the rate of 1.05 pounds daily and required 375 pounds of concentrates for 100 pounds of gain. Also, those on ladino consumed 40 percent less of the protein supplement than those on orchard grass. Chemical analysis of the two forages showed the ladino, on the dry-matter basis, to be much richer in protein and calcium, and lower in crude fiber.

SWEET CLOVER

This legume has gained some importance as a forage crop for hogs. It is successfully grown throughout the United States and southern Canada, thriving in both humid and semi-arid climates. On poor sandy soils it thrives much better than alfalfa or clover. The white-flowered species is more commonly grown in the eastern United States and the yellow-flowered more commonly in the northern Great Plains area. The latter is somewhat finer of stem and more prostrate in habit of growth. In the South it is called melilotus. Like alfalfa it has a very deep root system and therefore withstands drought well. It does best on lime-rich soils. On account of the presence of a bitter-tasting substance, called cumarin, pigs do not eat it readily. It is more palatable in early summer than later chiefly because it grows rank rapidly and the tender new growth is less bitter to the taste. The second year's

[8] J. L. Gobble, R. C. Miller, P. T. Ziegler, and F. L. Bentley, Bul. 516, 1949.

growth is not suited to pigs; since it assumes a coarse, woody character early in the season, it serves better for shade than for feed.

The early studies of Kennedy and Evvard of the Iowa Station[9] showed that the first year's growth of sweet clover has considerable value as a forage for pigs. They pastured 22 38-pound pigs on an acre from June 22 to November 10. On a ration of corn, with some meat meal added during the latter part of the period, the pigs made a gain of 1.02 pounds daily. On the second year's growth similar pigs gained only 0.53 pound daily.

Sweet clover versus alfalfa and rape. First year's growth of sweet clover, seeded in the early spring, has been compared with alfalfa and rape in trials both by the Illinois and Minnesota Stations, the averaged results being shown in Table 68. Corn and a protein supplement were fed to all lots in both experiments; full rations were fed in the Illinois experiment and three-fourths of a full ration in the Minnesota test. The average initial weight of the pigs was 66 pounds and the final weights varied from 200 to 224 pounds.

Table 68. Sweet Clover Compared with Alfalfa and Rape
(Average 2 Experiments)

Forage	*Average Length of Tests*	*Average Daily Gain*	*Concentrates to Produce 100 Pounds Gain*
	days	lb.	lb.
Sweet clover	123	1.125	408
Alfalfa	126	1.170	388
Rape	126	1.210	365

In the Illinois experiment the pigs on sweet clover gained as rapidly as did those on alfalfa or rape, although requiring more concentrates for a given gain. In the Minnesota test only three-fourths of a full grain ration was fed, which permitted a more reliable valuation of the forages. Under these conditions the pigs on sweet clover gained only 1.05 pounds daily, while those on alfalfa and rape gained, respectively, 1.14 and 1.22 pounds daily. The cost of the gains on sweet clover in this experiment was $1 per hundredweight higher than on either of the other forages. In both experiments a small cutting of hay was taken from both the clover and alfalfa lots. In neither test did the pigs eat the sweet clover with relish, especially at first.

[9] W. J. Kennedy and John M. Evvard, Bul. 136, 1913

The carrying capacity of sweet clover is equal if not superior to that of alfalfa.

Robison of the Ohio Station pastured spring pigs on first year's growth of sweet clover and soybeans from July 18 to September 26 in two trials. Fed the same amount of grain, which was nearly a full ration, the pigs on the soybeans gained more than 20 percent faster at a cost of 17 percent less concentrates for a unit of gain. He reported, however, that the sweet clover would have furnished pasture for a much longer time than the soybeans. Smith of the Washington Station found in one trial that sweet clover and alfalfa were equally efficient as forages when the pigs were fed limited rations. He reported that the sweet clover remained green for a longer period during the drier part of the summer than did the alfalfa. At the Kansas Station, Weber and associates found sweet clover to be a very satisfactory hog forage. In two trials it proved nearly as valuable as alfalfa. In one of the tests the season was unusually dry and the pigs on sweet clover gained considerably faster than did those on the alfalfa.

OTHER CLOVERS

Because of its leafy character, fine stem, and good yielding powers, *alsike* is probably the equal of red clover as a forage for pigs. It is a long-lived perennial and thrives particularly in a cool climate and with abundant moisture. It rarely winter-kills and does well on water-logged or "clover-sick" soils. Due to its tardier growth, it is not available for grazing so early in the spring as red clover. *Mammoth* clover is not as highly regarded, as a rule, as medium red, chiefly because of the coarse quality of its growth. It is a heavy yielder, however, and does well on thin sandy soil. *White* clover is a persistent-growing perennial which adds greatly to the value of permanent pastures of both the North and South. *Crimson* clover is an annual particularly suited to the climate and soil of the South Atlantic states. It provides valuable forage for hogs during the winter. Varieties of bur clover are successfully grown and used as forage crops for hogs in the South and West. It is regarded as a valuable supplement in Bermuda pastures. *Lespedeza,* or Japan clover, is one of the valuable legumes in the South and is beginning to command attention in the North. It is an annual, but reseeds itself every year. In every section of the country some species of clover may be grown successfully for forage purposes.

Fig. 45. Pigs grazing alfalfa. Because of its adaptability, deep root system, abundant yield, and richness in protein, minerals, and vitamins, alfalfa is unexcelled as a forage crop *(photo by Allen)*.

ALFALFA

Alfalfa is one of the most important swine forages. It combines the merits of unusual palatability and richness in protein, minerals, and vitamins with heavy yielding powers, permanency, the ability to furnish a uniform supply of forage through a long growing season, and exceptional ability to withstand drought. It is a deep-rooted perennial and does best when the water level is not too close to the surface.

pounds of shelled or ear corn daily for each hundredweight of pig made an average total gain of 3191 pounds on one acre of forage and 7752 pounds of shelled corn. One hundred pounds of pork, in other words, were produced for 243 pounds of corn with forage. On similar plots, the yield of alfalfa hay was 5.58 tons to the acre. With hogs at $7 per hundredweight and corn at $1.07 per hundredweight, it was figured that the net return from an acre of forage was $140.42 for the season, or a return equivalent to $25.16 a ton for the hay.

Alfalfa versus rape. Six experiment stations have studied more or less extensively the relative merits of alfalfa and rape as forages for pigs. In all 27 comparisons have been made, the summarized results of which are shown in Table 69. The trials were all with spring pigs which averaged in weight from 45 to 82 pounds at the start and covered periods ranging from 80 to 190 days. In most of the experiments practically full rations were fed; in three of the trials one-half to three-fourths full rations only were allowed. A protein supplement was fed with the grain in all cases.

Table 69. Alfalfa versus Rape
(Average 27 Experiments)

Forage	*Average Number Pigs per Acre*	*Average Length of Tests*	*Average Daily Gain per Pig*	*Concentrates Eaten for Each 100 Pounds Gain*
		days	lb.	lb.
Alfalfa	18	121	1.188	358
Rape	17	121	1.144	361

It would appear from these average results that Dwarf Essex rape is nearly the equal of alfalfa as a forage. In most of the experiments the pigs on alfalfa gained faster, while in a majority of the trials those on rape made their gains on less concentrates; the average cost for all was about the same. A significant point, which does not appear in the table, is that in a number of the experiments 1½ to nearly 2 tons of cured hay to the acre were taken from the alfalfa lots (see Table 65, Clover vs. Alfalfa; Table 68, Sweet Clover vs. Alfalfa; Table 76, Sudan Grass vs. Alfalfa).

Brome grass versus alfalfa. Becker and associates of the Illinois Station [11] compared brome grass with alfalfa for growing and fattening pigs. Fifteen pigs on an acre of brome grass and 16 comparable

[11] D. E. Becker, J. L. Krider, R. F. VanPoucke, and W. E. Carroll, Mimeo. Rpt., Ill. Swine Growers' Day, April, 1946.

pigs on an acre of alfalfa were full-fed a ration of shelled corn, soybean meal, and minerals from an initial weight of 53 pounds to about 200 pounds. The pigs on brome grass gained 1.26 pounds daily; those on alfalfa gained 1.37 pounds daily. The alfalfa pigs reached market weight about 1 week earlier than those on brome grass. The dry feed consumed for each 100 pounds of gain was 376 for the pigs on brome grass, and 353 pounds for those on the alfalfa. The experimenters reported that the brome grass was very palatable, withstood tramping reasonably well, and remained succulent throughout the summer and early fall.

In another trial these investigators compared two systems of feeding on brome grass. One lot was fed corn and minerals alone; a second lot was hand-fed in addition soybean meal in an amount to represent about 10 percent of the dry ration. There were 20 pigs in each group allotted each to an acre. The results were strongly in favor of the pigs fed the soybean-meal supplement. They consumed more feed, gained more than 20 percent faster, and reached market weight 26 days earlier. Also, less feed was required for a unit of gain. In still another comparison it was shown that partly grown pigs of a weight of 125 pounds at the start made faster and cheaper gains up to market weight when supplied the supplement in addition to the basal ration of corn and minerals.

DWARF ESSEX RAPE

Rape is a quick-growing succulent annual, unsurpassed by crops of this class as a forage for pigs. The plant is unusually tender and succulent and is eaten with relish and no waste. Although not a legume, it ranks with alfalfa and the clovers as a cheap source of protein and a balancer of corn. Rape is a very heavy yielder and possesses unusual carrying capacity. It may be heavily stocked and intensively grazed for a short period or it may be handled so that it will furnish grazing until freezing. Planted in the fall, rape has proved a valuable winter forage in the South. Although it does best in a cool moist season, it stands next to alfalfa in its ability to withstand drought. It may be planted so as to supply forage any time during the season, although the earlier planting yields heaviest. With timely rains, rape continues to renew itself throughout the summer if not pastured too closely. For this reason, alternating the pigs on different lots ensures the best results.

Rape mixes well when sown with Canadian field peas, oats, or

clover. It is often seeded with oats, and will come on and furnish valuable succulence after the grain is harvested. If sown between the corn rows at the time of last cultivation, it will ensure better results when hogging down the corn. Rape may be sown broadcast or drilled in rows 24 to 30 inches apart. The latter method of seeding is usually to be preferred as it may be cultivated, it will yield heavier, and the pigs will destroy less by tramping. Pigs recently weaned should be turned on when the plants are 14 to 16 inches high; with fall pigs, the growth should be, preferably, 16 to 18 inches high.

Every year a few feeders report that their pigs refuse to eat rape, but at none of the stations of the country where experimental studies have been made of this forage have any results been obtained which would tend to support such a conclusion. Its tendency to cause sores and blisters on thin-skinned pigs is not considered serious. The trouble may be largely avoided by keeping the pigs out while rain or dew is on the plants. Pigs badly blistered have been successfully treated by washing or spraying with a disinfectant, then greasing with lard or vaseline (see Table 66, Clover vs. Rape; Table 68, Sweet Clover vs. Alfalfa and Rape; Table 69, Alfalfa vs. Rape).

Early versus late rape and other forages. An experiment conducted during the summer of 1909 at the Iowa Station tested the relative merits of the following forage crops; early-sown rape; late-sown rape; a mixture of oats, clover, and rape; a mixture of Canadian field peas, oats, and rape; and bluegrass and timothy pasture. The rape in both lots was broadcasted, the early planting being seeded May 4 and the late July 5. The mixtures in the other two lots were drilled May 4. A full ration of ear corn was fed all lots, supplemented during the last 30 days by the addition of 10 percent of meat meal. The results are shown in Table 70.

With those lots fed for approximately the same length of time, the mixture of oats, clover, and rape gave the best results. In this lot the gains were fastest, the amount of grain fed for each 100 pounds of gain made was least, and the amount of pork credited to one acre of forage greatest. Although the amount of grain required to produce 100 pounds of gain was greater in the early rape lot than in the lot on oats, peas, and rape, the gains were faster. As measured by the amount of pork or concentrates credited to each acre of forage, the latter crop was more profitable. The bluegrass and timothy pasture gave returns very much less favorable than the other forages, owing, no doubt, to the fact that this crop did not supply as much protein,

Table 70. Early- versus Late-sown Rape versus Forage Mixtures

Forages	*Number Pigs per Acre*	*Length of Period*	*Average Daily Gain per Pig*	*Concentrates Eaten for Each 100 Pounds Gain*	*Pork Credited 1 Acre of Forage*[b]
Early-sown rape	17	147	0.81	326	371
Late-sown rape	19	104	1.36	371	195
Oats, clover, and rape[a]	17	147	0.91	318	458
Canadian field peas, oats, and rape	17	147	0.85	339	419
Bluegrass and timothy pasture	14	165	0.72	393	28

[a] Mixture of 48 pounds of oats, 8 pounds of red clover, and 2 pounds of rape sown to an acre.

[b] Figured on the basis that 4 pounds of grain would have been required to produce 1 pound of gain under dry-lot conditions.

minerals, or vitamins to balance the straight corn fed during most of the experiment. The value of a late planting of rape is well shown by these results. The more rapid daily gains in this lot as compared with the early rape lot are probably to be explained by the larger size of the pigs and also by the fact that straight corn was fed for a shorter proportion of the time.

In the forage experiments at the Iowa Station in 1911, rape alone proved slightly inferior to a mixture of oats, Canadian field peas, and rape.

Winter rape. Rape is a valuable winter and spring forage crop in the South. Planted in September or October it will furnish grazing usually for a period of about 3 to 4 months, from January to May, and will support on the average at least six well-grown shotes to the acre.

COMBINATIONS: CANADIAN FIELD PEAS, OATS, CLOVER, RAPE

As a rule, a mixture of two or more plants possessing similar requirements in temperature and soil give a heavier yield as a forage than any one of the crops grown separately. Also, a more uniform supply of succulence may be provided by selecting for the combination crops which make most of their growth in successive periods of the summer. For these reasons, various mixtures of the above crops are commonly planted and successfully used for forage purposes.

In the latitude of the northern Corn Belt and farther north, the Canadian field pea is a standard forage crop for pigs. It is a rapid-

growing legume, occupying the same class as the alfalfa and the clovers in its ability to furnish protein. Five or six weeks after planting it is ready to use. It is a decided cool-weather crop and does best when planted as early in the spring as the ground can be worked. It should not be confused with the cowpea, which is extensively grown in the South. It is particularly sensitive to heat and wilts early in a dry hot summer. It should always be grown with oats, or some such crop, which will support the vines; otherwise considerable loss will result from trampling and mildew. In the North the pigs are sometimes not turned in until the pods are well filled, although the more common practice is to use it as a green crop by pasturing it after the growth is about 10 inches high.

Forage mixtures for fall pigs. In the summer of 1910, the Iowa Station fed four lots of fall pigs on different forage combinations. The forages tested were made up of a mixture of oats and rape in combination with red clover, hairy vetch, or Canadian field peas in the first three lots, while in the fourth a mixture of oats and clover was alternately grazed with rape.

The crops were seeded April 4 by drilling in the following proportions and quantities to the acre: Lot I, 48 pounds of oats, 8 pounds red clover, and 2 pounds rape; Lot II, 48 pounds oats, 90 pounds peas, and 6 pounds rape. The mixture of oats and clover for Lot IV was drilled in rows 8 inches apart. The rape was drilled in rows 24 inches apart and given three cultivations. The experiment began May 26 and closed November 11. Each lot was fed a grain ration of ear corn with about 7 percent of tankage added. Full rations were fed during only the last 85 days of the trial. The results are shown in Table 71.

Table 71. A Comparison of Clover, Hairy Vetch, and Canadian Field Peas in Combination with Oats and Rape for Fall Pigs

Forages	*Number Pigs per Acre*	*Length of Test*	*Average Daily Gain per Pig*	*Concentrates Eaten for Each 100 Pounds Gain*
		days	lb.	lb.
I. Oats, clover, and rape	11	168	1.22	445
II. Oats, vetch, and rape	11	168	1.21	447
III. Oats, peas, and rape	11	168	1.31	414
IV. Oats and clover alternated with rape	13	168	1.17	460

All the pigs were extremely heavy at the close of the experiment. For this reason the amount of feed required to produce 100 pounds

of gain was considerably greater than that previously shown necessary for spring pigs. Also, the pork credited to each acre of forage was less than that usually obtained with younger pigs and similar crops. Of these three forage mixtures, oats, vetch, and rape proved the least profitable. The authors stated that the vetch was of little value in the mixture. It came on and made good growth in July and August, but the pigs ate little of it. As the result of their observations, they strongly advise against the use of hairy vetch as a hog pasture in Iowa. The returns in Lot IV, in which oats and clover were alternated with rape, were disappointing. After the rape had been well eaten down early in the season, the pigs were changed to oats and clover. From late July until the end of the season the pigs were on the rape again, as the oats and clover furnished practically no feed during this time.

Oats versus other forages. In Table 72 are shown the results of an experiment at the Iowa Station in 1911. In this test a comparison was made of a mixture of oats, Canadian field peas, and rape with oats alone, and with rape alone. The pigs in all three lots were turned in June 13. At this date the oats in the oats-alone lot were just beginning to head.

Table 72. A Comparison of Oats with Other Forages for Spring Pigs

Forages	*Number Pigs Per Acre*	*Length of Test*	*Average Daily Gain per Pig*	*Concentrates Required for Each 100 Pounds Gain*
		days	lb.	lb.
Oats	30	90	0.63	365
Rape	43	160	1.07	385
Oats, Canadian field peas, and rape	31	160	1.16	370

The experiment was continued for each forage lot as long as feed remained, the oats in the oats-alone lot being exhausted 70 days earlier than the forages in the other two. The pigs averaged 26 pounds when the experiment began and were given full rations of ear corn with about 5 percent of meat meal.

Because of the exceptional number of pigs carried on an acre of the rape, this forage proved to be the most profitable. This lot was pastured at the rate of 30 pigs an acre until September 11 when the number was increased to 60. Seven extra pigs were added to the lot on oats, peas, and rape for 30 days in the last part of the experiment. The oats alone proved to be a poor forage with this method of pastur-

ing, although the volunteer growth supplied considerable green feed during the late summer.

RYE : WHEAT

One of the most valuable characteristics of green rye as a forage crop is that it furnishes a supply of green succulent material rich in vitamins and protein when the other forages and pastures usually are of little value. Balbo rye is particularly palatable, yields heavily when grown on good soil, and has proved a boon on the Corn Belt hog farm in maintaining thrift and reproductive performance in the breeding herd.

If planted early in the fall, rye will supply valuable grazing in an open winter until late the next spring. If pastured lightly and the pigs are not allowed to remain on it too late, it will yield its normal harvest of grain. The pigs are often allowed to remain on the land until after the crop has matured, or it may be pastured heavily in the spring and the land early prepared for other crops. When seeded between the corn rows late in the summer, it will supply valuable succulence for the shotes when "hogging-down" the corn, or for grazing by the bred sows and gilts after the corn has been harvested.

Wheat is very much like rye. In the winter wheat belt, drilled in August or September, it will supply succulence and food in an open winter until time to prepare the land for spring planting. It does not pay usually to leave the pigs on to harvest the matured grain.

Experiments by Martin of the Arkansas Station[12] showed that fall-seeded rye, oats, and wheat were of practically equal value as grazing crops for pigs during the winter. Compared with soybeans, planted in the spring and carried over for winter grazing, these cereals proved more valuable as forages during January and February. His feeding trials showed that 70-pound pigs can be fattened successfully and economically on a self-fed ration of corn and minerals when grazing any of the cereals.

At the Michigan Station, McMillen[13] found that August-sown rye, seeded at the rate of 1½ bushels per acre, was excellent as a means of extending the normal pasture season. Grazed by brood sows during late fall and early spring, it proved cheap insurance against possible breakdowns during late gestation, weak litters, and lactation failures.

[12] Edgar Martin, Bul. 321, 1935.
[13] W. N. McMillen, Mich. Qt. Bul., Vol. 28, No. 4, 1946.

BLUEGRASS: TIMOTHY

Although bluegrass pasture has its largest use for horses and cattle, it may be employed profitably for pigs during the spring and autumn, when the usual forage crops are often not available. On those farms where the production of forage crops and the feeding of balanced rations has been given little if any attention, it has been of large value as a supplement to the corn ration. It may do well on land too rough for crops; it is permanent, cheap, and a valuable adjunct to other forages. Like any crop, the yield and quality of bluegrass varies widely with the kind of soil on which it is grown, the temperature, the rainfall, and the way in which it is managed.

Because it seeds in the spring or early summer and remains in a more or less dormant state until autumn, however, it does not rank high as a sole forage for pigs. The good hogman will seek to provide other forage crops, reserving his bluegrass pastures for the other classes of stock. Hogs have ruined many fine bluegrass pastures.

Bluegrass and timothy versus clover and alfalfa. In Table 73 are given the results of an experiment conducted at the Iowa Station in 1909 in which a pasture of bluegrass and timothy was compared with alfalfa in one case and clover in another. The pigs were of spring farrow and weighed between 33 and 34 pounds on June 4 when the test began. In addition to the forage, the pigs of each lot were given a full feed of ear corn, supplemented during the last 39 days of the trial by the addition of 10 percent of meat meal. The experiment covered a period of 165 days, practically the entire time from weaning to marketing.

Table 73. Bluegrass and Timothy versus Clover and Alfalfa

Forages	*Average Number Pigs per Acre*	*Average Daily Gain per Pig*	*Concentrates to Produce 100 Pounds Gain*	*Concentrates Saved by 1 Acre Forage*	*Pork Accredited 1 Acre Forage**
		lb.	lb.	lb.	lb.
Bluegrass and timothy	13.9	0.72	393	111	[illegible]
Alfalfa	13.9	0.99	367	745	[illegible]
Clover	13.9	1.07	352	11[illegible]5	[illegible]
Clover	13.9	1.07	355	1121	[illegible]

* Figured on the basis that 4 pounds of [illegible] for each pound of gain in [illegible].

Considering that straight corn was fed in all lots [illegible] last 39 days, the gains made were [illegible]

pork credited to each acre of forage would undoubtedly have been greater if a small quantity of meat meal had been fed earlier in the test. The relative merits of the crops are well shown by the rates of gain and the concentrates required to produce 100 pounds of gain. The superiority of the legumes clover and alfalfa, over the bluegrass and timothy, was marked. Clover gave slightly better results in this experiment than did alfalfa, although the authors of the bulletin, as the result of other studies, rank it below alfalfa in value. The uniformity of the results from the two lots on clover testifies to the care exercised in making the different lots comparable.

Although timothy is not a valuable forage crop for pigs, it is sometimes profitable to make use of it for this purpose. It is very succulent and palatable, but low in its content of protein. It supplies considerably less protein in proportion to its carbohydrates than does either rye or bluegrass. As shown by experiments conducted at the Iowa Station in 1906, the feeding of pigs on timothy gave fairly satisfactory results when compared with dry-lot feeding. In Table 74 are given the averages for four lots on timothy and four comparable lots fed in the dry yard. The pigs in both the dry and forage lots were fed balanced rations.

Table 74. Timothy versus Dry-lot Feeding
(Average 4 Experiments)

	Number Pigs Grazed to Acre	*Average Initial Weight per Pig*	*Average Daily Gain per Pig*	*Concentrates Eaten for Each 100 Pounds Gain*	*Pork Credited 1 Acre Forage*
		lb.	lb.	lb.	lb.
Dry lot	—	59	0.938	461	—
Timothy	11	57	1.240	406	197

SWEET SORGHUM

Sorghum is used more or less extensively as a forage for swine in the southern part of the Corn Belt and farther south and in the semiarid regions of the Southwest. Its chief merit is its ability to furnish a heavy tonnage of succulent feed in a dry hot season. It should be pastured ordinarily while the plant is young and tender, or when 1 to 2 feet tall, although it is sometimes allowed nearly to mature before turning in. Results of feeding trials conducted at the Alabama Experiment Station, however, showed that the latter method did not give profitable returns for the crop. The following tabulated results were secured at the Missouri Experiment Station when pastured early. The

plants were 1 to 2 feet high when the experiments began. The pigs were fed balanced rations and were turned in when weighing from 60 to 90 pounds each.

Table 75. Results from Pasturing Sorghum

Year	*Number Days Pastured*	*Number Hogs per Acre*	*Total Gain per Acre*	*Total Concentrates Fed per Acre*	*Concentrates Fed for Each 100 Pounds Gain*
			lb.	lb.	lb.
1910	105	14	1412	6584	460
1912	68	16	869	3112	350
AVERAGE	86.5	15	1145	4548	405

The chief fault of this crop as a forage is its coarseness and its carbonaceous nature. It is more suitable for cattle or sheep than it is for pigs.

SUDAN GRASS

This quick-growing annual is very much like the sorghums in its carbonaceous character, climatic adaptation, and habits of growth, although it is finer of stem and more leafy. It is especially adapted to the Southwest where the rainfall is uncertain, but does well also in the more humid areas. It is grown successfully from South Dakota to Texas, as well as in other states. For pigs it should be broadcast, 20 to 25 pounds of seed to the acre. Since it is rank in growth it is often advisable to cut it back when grazed by young pigs. It will supply grazing normally from about July 1 to November 1, and its carrying capacity is practically equal to that of alfalfa. Because of its carbonaceous character, however, it is more necessary to feed a protein supplement with the grain to pigs on this forage.

Sudan and alfalfa compared. The value of Sudan grass as a forage for spring pigs is indicated by the results of experimental studies made at the Kansas, Nebraska, and Pennsylvania Stations, in which it was compared with alfalfa. A summary of these results is given in Table 76. Altogether there were 10 comparisons made involving the use of 325 pigs. The pigs averaged from 45 to 81 pounds at the beginning of the different experiments, the grazing period varied from 56 to 120 days, and the number of pigs grazed to the acre, which was the same for both forages in each case, was 23, on the average. In two trials 15 pigs only were grazed to the acre, and in one there were 32 to the

aere. In each experiment the same ration was fed to both lots. Corn was the only concentrate fed in five cases, while in the other five a protein supplement of tankage, or a mixture of wheat middlings and tankage, was fed with the corn. Full grain rations were fed in five of the trials, and one-half to three-fourths full rations in five others.

Table 76. Sudan Grass Compared with Alfalfa
(Average 10 Experiments)

Forages	*Average Number Pigs Grazed per Acre*	*Average Length Grazing Period*	*Average Daily Gain*	*Concentrates to Produce 1 Cwt. Gain*
		days		
Alfalfa	23	65	0.79	302
Sudan grass	23	65	0.69	341

In every case the pigs on alfalfa gained faster than those on Sudan grass; the difference in favor of the alfalfa-fed pigs was greatest in those experiments in which limited grain rations were fed. The amount of grain eaten for each hundredweight of gain was 14 percent less for the pigs on alfalfa, on the average. The difference in the economy of gains was greater than this in those trials where limited amounts of concentrates were fed. The observation was made that pigs weighing 80 pounds when turned in do very much better on Sudan grass than do pigs weighing 45 pounds. At Kansas 70-pound pigs could not keep it pastured down, necessitating cutting twice between July 3 and November 1. Although not equal to alfalfa, Sudan grass made a very favorable showing in these trials.

Martin of the Arkansas Station[14] found Sudan grass, as well as sweet sorghum, superior as a summer-grazing erop for pigs to either soybeans or cowpeas, espeeially when no protein supplement was fed. When tankage was fed with eorn and minerals, sweet sorghum and Sudan grass were praetieally equal. Sudan grass proved to be more palatable than either soybeans or eowpeas, espeeially when elosely grazed.

SOYBEANS

Soybeans have beeome an important legume in the United States. Although primarily a southern erop, the rapid inerease whieh has oceurred in its eommereial production in reeent years has been the result largely of a marked inerease in aereage in the North Central

[14] Edgar Martin, Bul. 321, 1935.

states, particularly in Illinois. This increased acreage is not due, however, to the popularity of the crop as a green forage plant for pigs, but rather to its use for hay and seed.

As a forage plant it is a good soil builder, is rich in protein, does fairly well on sandy soils, and may be profitably grazed by pigs fed corn only. The stock of the plant is rather stiff and woody in most varieties, however, and the leaves shatter easily. As a result it does not supply satisfactory pasturage for a long period.

Godbey of the South Carolina Station grazed spring pigs on soybean forage at the rate of 12 pigs to the acre during each of four years. They were turned in when the plants were about 18 inches tall, at a weight of 50 pounds. They were grazed for a period of 106 days, on the average, and weighed 200 pounds when the trials closed. The ration fed was a full feed of corn and a half-feed of tankage. By comparing the results with those obtained by comparable groups of pigs fed the same ration in dry lots, it was calculated that an acre of beans saved 1184 pounds of feed (corn and tankage), or should be given credit for producing 376 pounds of pork. As a result of these experiments with soybeans and other crops, the author concluded that soybeans are the best summer and fall forage for growing and fattening pigs in his state. By grazing the beans in the green and mature stages and by using varieties which mature at different times, it was claimed that the grazing season could be extended to six months.

Robison of the Ohio Station in an experiment in which 45-pound pigs were turned in on the soybeans July 15, when the beans were about 10 inches high, and continued for 77 days or until November 10, found the forage considerably inferior to rape or clover. In a later experiment the beans gave better results than sweet clover, the grazing period being from July 18 to September 26. Weaver reports that soybeans have not given as good results in Missouri as alfalfa, clover, rape, Sudan grass, or sorghum. Haskell of the U S Department of Agriculture recommends the substitution of soybeans for cowpeas on the heavier types of soil in the coastal plains, but says they are a very uncertain crop on the light soils which are characteristic of this area.

The use of soybeans as a seed crop to be hogged-off in the fall either alone or with corn is treated in Chapter XI

tein as a feed, and its general adaptability to southern conditions. It does well on light sandy soils and, even with scant attention, will produce a short summer crop of hay or forage. It will produce a good crop when planted late, following oats or other winter crops. Usually the leaflets start falling as soon as the pods begin to ripen, and it is very sensitive to frost.

At the Alabama Station, Gray pastured pigs on fairly mature cowpeas from August 12 to November 5. Fed a half-feed of corn and tankage, the pigs on forage gained 0.97 pound daily, while a comparable group of pigs fed a full ration of corn and tankage and confined to a dry lot gained only 0.54 pound daily. The crop did not prove profitable in this experiment, however, because the stand was so poor that the pigs were grazed at a rate of less than three to the acre. Based on the results of six trials at the Missouri Station, Weaver reported that cowpeas gave satisfactory results in only one out of the six years tried. On the average 13 pigs were grazed to the acre for a period of one month. The amount of pork credited to each acre averaged 149 pounds.

BERMUDA GRASS: CAT-TAIL MILLET

Bermuda grass is to the South in economic importance what bluegrass is to the North. It is adapted to the same areas as cotton and does best on well-drained rich soil. Haskell recommends that it be given a place on every hog farm of the South as a permanent pasture.

Cat-tail, or pearl, millet, seeded in the early spring, promises to become a valuable forage for pigs in the South. Since it is a strong rank grower and soon becomes coarse, it is advisable to pasture it heavily and early. Early grazing also induces stooling, which tends to increase its carrying capacity. Ordinarily it will supply a palatable forage from the middle of April to the middle of July.

RECOMMENDED FORAGES FOR DIFFERENT AREAS

On every hog farm there probably is some one forage, or succession of forages, which meets most efficiently the requirements for green feed. The one should be selected which meets the needs and is best adapted to the soil, climate, and crop-rotation plans. In the following tables there are listed the forage crops which are recommended by various authorities in the different areas, together with suggestions relative to rate of seeding, time of planting, and rate and time of grazing. In the longer tables all adapted crops have been listed without reference to their relative merits, the purpose being to give useful

information about their production, yields, and use which will assist the reader in working out a plan that will be most satisfactory for his own particular farm.

Table 77. Temporary and Permanent Forages for Iowa Swine [15]

Kind of Forage	*When Sown*	*Rate per Acre*	*Length of Pasture Season*	*No. Hogs per Acre*	*Remarks*
Rye (Winter)	September	6 pks.	Late fall, early spring until May 15th	6 sows and litters	Rye pasture should be plowed about May 15th and planted to some crop
Rape (Dwarf Essex)	Oat seeding time	6 lb.	Rape should reach 8 or 9 in. before pasturing, lasts until winter	20 to 25 growing hogs	Oats may be sown at the rate of a bushel or so per acre. Rape is sometimes sown with oats which is cut for grain; after which rape comes along and makes fall pasture.
Alfalfa	Spring, with small grain	12 lb.	May be pastured late fall first season, after that alfalfa is a full-season pasture	15 to 30 depending on how hogs are fed	6 lb. brome seed may be sown with alfalfa
Sweet Clover (Biennial)	Seeded with small grain	8 to 10 lb.	Same as alfalfa	15 to 30, as with alfalfa	One bushel of oats should be seeded with the sweet clover; 2 to 3 lb. red clover and 1 to 2 pounds alsike should be sown with the sweet clover to carry on
Red Clover	Same as alfalfa	8 lb.	Same as above for alfalfa	12 to 20, as with alfalfa	
Sudan	Usually after corn planting	15 lb.	Until frost	Same as for alfalfa	Sudan is used mostly as an emergency pasture for hogs
Ladino	Early spring	1½ to 2 lb.	Same as for alfalfa	Same as for alfalfa	Seeded with 1 bushel oats to the [illegible] 5 pounds [illegible] times seeded [illegible]

[15] E. L. Quaife, Agr. Extension Service, Iowa State College, [illegible]

Table 78. Pasture Crops for Indiana[16]

Crop	*Date and Method of Seeding*	*Seed Required per Acre*	*Approximate Time Ready to Graze*	*Approximate Grazing*
Alfalfa Timothy Ladino clover	Feb. to May or early Aug., broadcast or drill	Alfalfa 8 lb. Timothy 2 lb.	Late summer to Sept. 1; 2d year, May to Sept. 15	5 to 7 mo. for several seasons
Ladino clover	Feb. to May or early Aug., drill or broadcast	Ladino 1 lb.	Late summer to Sept. 1; 2d year May to Sept. 15	6 to 8 mo. for several seasons
Red clover, Timothy	Feb. to Apr. 15, drill or broadcast	Timothy 4 lb. Red Clover 8 lb.	1st year to Sept. 1; 2d year from May on	Rest of summer and next season
Birdsfoot trefoil Ladino clover Timothy	Feb. to April or early Aug., drill or broadcast	B. trefoil 4 lb. Ladino c. ½ lb. Timothy 4 lb.	2d year from May on	May to Nov.
K. Lespedeza[a]	Feb. to April, broadcast	15 to 20 lbs.	July 1 to 15	Until frost
Oats and rape	March to May, drill or broadcast	Oats 8 pecks Rape 3 to 5 lb.	May 15 to June 1	Rape until frost oats 4 to 6 weeks
Rape	March to July, rows or broadcast	2 to 6 lb.	May 15 to Aug. 15	2 to 4 mo.
Sudan grass	May 15 to July, drill	25 to 30 lb.	July 1 to July 15	Until frost
Balbo rye	Aug. to Nov., drill	6 to 8 pecks	Late fall and early spring	
Rye grass[a] Winterbarley[a]	Aug. to Oct., drill or broadcast	10 to 15 lb. 8 to 10 pecks	Late fall and early spring	

[a] For Southern Indiana.
[16] M. O. Pence and C. M. Vestal, Ind. Exp. Sta., Leaflet No. 226 rev., 1949.

Table 79. Suggested Crops for "All-Year" Hog Pastures in Missouri [17]

Grazing Time	*January and February*	*March and April*	*May, June, July, Aug., Sept., and Oct.*	*November and December*
(A) On sweet fertile soil	Blue grass (not grazed previous summer or fall) *OR* Early fall seeded small grain *OR* Tall fescue-ladino clover	Early fall seeded small grain *OR* Established timothy-lespedeza not grazed during winter	Alfalfa *OR* Alfalfa-brome *OR* Red-clover *OR* Ladino clover	Tall fescue-ladino clover *OR* Early fall seeded small grain
(A_1) On sweet soil, medium fertility	Bluegrass not grazed previous summer and fall *OR* Early fall seeded small grain	Same as above	2d year sweet clover to July 15th then lespedeza, 1st year sweet clover to Oct. then early seeded small grain pasture	Early seeded small grain *OR* either timothy-lespedeza *OR* bluegrass neither grazed during summer or early fall
(B) On sour fertile soil	See A_1	Same as above until June	After June 1st, dwarf essex rape *OR* Rape and oats	See A_1
(B_1) On sour soil, medium in fertility	See A_1	Same as above until June	After June 1st, sudan grass *OR* timothy-lespedeza *OR* red top-lespedeza	See A_1

[17] L. A. Weaver, Information to the Author, 1950.

Table 80. A Four-year Kansas Crop Rotation for Pasturing Hogs[15]

Year	*Field No. 1*	*Field No. 2*	*Field No. 3*
First	First year sweet clover	Second year sweet clover Rye sowed in Sept.	Rye in early spring. Sudan grass sowed in May
Second	Second year sweet clover Rye sowed in Sept.	Rye in early spring. Sudan grass sowed in May	First year sweet clover
Third	Rye in early spring. Sudan grass[a] sowed in May	First year sweet clover	Secood year sweet clover Rye sowed in Sept.
Fourth	First year sweet clover	Secood year sweet clover Rye sowed in Sept.	Rye in early spring. Sudan grass sowed in May

[a] In some sections perhaps rape might be substituted for the Sudan grass, or wheat for rye.
[15] C. E. Aubel, Kans. Exp. Sta., Bul. 314, 1943.

Table 81. Grazing Crops for Michigan[16]

Pasture Crop	*Rate of Seeding*	*When Seeded*	*When Available for Pasture*
Rye	6–8 pks.	Late summer or early fall	March, April, May; Sept. 15 to Dec. 15
Bluegrass	2–5 lb.	Early spring	April to June; Sept. and Oct.
Alfalfa or clover	6–10 lb.	Spring or summer	May 1 to Sept. 15
Alfalfa and brome grass	6–8 lb. 1–3 lb.	Spring or summer	May 1 to Sept. 15
Rape and oats	3–6 lb. 1–3 lb.	Early spring	June 10 to Nov. 15
Sudan grass	15–20 lb.	Late spring	July 10 to Sept. 15

[16] W. M. McMillen, Mich. Exp. Sta., Ext. Bul. 299, 1949.

Table 82. Forage Crops for Texas[20]

Pasture Crop	*Time to Seed*	*Seed Required per Acre*	*Approximate Grazing Period*	*No. Full-fed Market Hogs to 1 Acre*	*No. Sows with Litters to 1 Acre*
		lb.	*days*		
Alfalfa	Sept.–Oct.	15–25	150–180	15–25	4–6
Bur clover	Sept.–Oct.	15–20	40–60	15–20	4
Ladino clover	Sept.–Nov.	5–7	100–130	15–25	4–6
Common lespedeza	Mar.–May	20–25	90–100	15	4
Hubam clover	Mar. or Sept.	15–20	90–100	15–20	4
Vetch	Sept.–Oct.	25–35	90–100	15–20	4
Cowpeas	Mar.–May	30–40	55–70	10–12	3
Soybeans	Mar.–June	30–35	55–70	10–12	3
Rape	Sept.–Nov.	10–15	100–140	15–25	4–5
Oats	Sept.–Nov.	70–90	130–150	15–20	4
Barley	Sept.–Nov.	70–80	130–150	15–20	4
Wheat	Sept.–Nov.	30–60	130–150	15	3–4
Rye	Sept.–Nov.	50–60	120–130	15	3
Millet	Mar.–July	20–30	130–150	15–20	3–5
Sudan Grass	Mar.–June	10–15	130–150	15–20	3–5

[20] Fred Hale, Texas Agr. Exp. Sta., Information to the Author, 1950.

Table 83. Crops Which May Be Used in Providing All-year Grazing in Florida [21]

Month in Which Grazing Desired	*Grazing Crop*	*Planting Date*
January and February	Crimson clover	October and November
	Oats	October and November
	Rye	October and November
	Rape	October and November
	Runner peanuts	May and June
	Chufas	May and June
March	Oats	October and November
	Rye	October and November
	Rape	October and November
April	Oats—late grazing	September, October, and November
	Rape	November and December
	Millet—early grazing	March
May	Millet	March and April
	Oats	October and November
June and July	Early corn	March
	Spanish peanuts	March
	Cowpeas	April
	Soybeans	April
August and September	Corn	March and April
	Spanish peanuts	March and April
	Cowpeas	April and May
	Soybeans	April and May
	Chufas	May and June
October and November	Corn	April
	Runner peanuts	April and May
	Sweet potatoes	May and June
	Velvet beans	April and May
December	Early oats	October
	Rye	October
	Corn	April
	Runner peanuts	April and May
	Sweet potatoes	May and June
	Velvet beans	April and May
	Rape	October

[21] Walter J. Sheely, Fla. Exp. Sta., Bul. 138, 1948.

Table 84. Forage Crops Suitable to the Pacific Northwest[22]

Crop	Variety	Seeding Rate/Acre	Seeding Date	Time of Use	Number Pigs per Acre
Alfalfa[a]	Ladak Ranger	12 lb. 12 lb.	Spring Spring	2d year, May 1 to Oct.	18–20
Red Clover	Kenland	12 lb.	Spring	1st year, Fall; 2d year, April 1 to Oct.	15–20
Clover[b]	Ladino	4 lb.	Spring	2d year, May 1 to Oct.	18–20
Peas[c]	White Canadian Alaska	120 lb.	Spring	April 20 to Aug. 1 May 10 to Oct.	10–12
Sudan[c]	Sweet	35 lb.	May 10	July 1 to Oct.	12–14
Rye[c]	Abruzzi or Balbo	120 lb.	Sept. 1	March 15 to July 1	12–14

[a] Where soils are sufficiently sweet.
[b] On irrigated land only.
[c] For annual crop program.

Prof. J. S. Robinson of the Agricultural Extension Service, University of Tennessee, submits the following recommendations for winter and summer grazing (information to the author, 1950):

1. For winter pasture
   (a) Barley or oats seeded in August or early September. (b) 15 to 20 lb crimson clover seeded in August or early September with 3 to 4 bushels of oats or barley.
2. Supplementary summer pasture
   (a) Established stand of alfalfa, or alfalfa and orchard grass mixture. (b) lespedeza, Dallis grass, or Bermuda. (c) second growth of red clover. (d) harvesting third and fourth cuttings of alfalfa.

1. For fall, winter, and spring grazing
   (a) Oats planted in September or October; (b) white or crimson clover interplanted with oats in October; (c) rye grass planted in September or October; (d) Balbo or Abruzzi rye planted in September or October; (e) white Dutch or red clover interplanted with Kentucky 31 fescue in October.
2. For summer grazing
   (a) Sudan grass planted in April or May; soybeans planted in April or May; alyce clover planted in May or June.
3. Hogging-off corn and soybeans
   Early-maturing varieties of hybrid corn and soybeans that are planted in March will be matured enough to hog-off in July or August.

X Methods of Feeding on Forage

It will be appropriate now to give consideration to the various feeding practices followed in handling spring pigs on forage. This will involve especially a study of three important questions: first, should full or limited grain rations be fed; second, is it necessary to feed a protein supplement along with the corn or other grain; and third, is the feeding of minerals to be recommended?

FULL VERSUS LIMITED GRAIN RATIONS

Can the pig grow on forage alone? The pig's capacity to make gains on forage alone is limited. In fact, until a weight of 75 pounds has been reached, experiments generally show that even with the best of tender forage he is unable to maintain his weight for more than a very limited period. Morrow of the Illinois Station [1] failed to maintain 45-pound pigs on forage alone. During two seasons such pigs lost an average of 27½ pounds, all of which occurred during the first 10 days of the grazing period. The season, however, was one of unusual drought. During an eight-weeks' period from June to August in each of two summers, Rice of the same Station [2] kept 40-pound pigs on rape without concentrates. The first year the pigs made an average total gain for the entire period of 5.2 pounds, and the second year 1.25 pounds each. Three of the pigs died during the experiment. At the end of the test it appeared that none of the pigs could have survived much longer. At the Utah Station Sanborn successfully maintained 75-pound pigs on pasture without grain, each pig gaining 0.36 pound daily. The pasture was excellent, consisting of a variety of grasses and alfalfa. Arnett of the Montana Station [3] concluded from tests that there was danger of permanently stunting pigs weighing less than 35 to 40 pounds when maintained on pasture alone. He pastured

[1] Geo. E. Morrow, Bul. 16, 1891.
[2] John B. Rice, Bul. 247, 1924.
[3] C. N. Arnett, Bul. 128, 1919.

severl 30-pound pigs on red clover for 90 days with the result of an average total gain of 7 pounds for each pig during the period.

On good forage crops the 100-pound pig seems capable of maintaining his weight for several months, during which time he will continue to grow in height and length while losing fat. In all such cases, however, much will depend on the age, condition, and previous feeding habits of the pig, as well as the quality and abundance of the forage. The nutrients contained in 4 or 5 pounds of good clover forage should, theoretically, be sufficient to maintain the 50-pound pig.

The problem of the practical feeder, however, is not one of maintenance, but of production. He is not so much concerned with the possibility of maintaining his pigs on forage alone as he is in a method of feeding which will produce the gains necessary to ensure market finish or breeding development. An important principle to remember in this connection is that only that part of the ration fed above maintenance needs is available for growth or fat production. The returns secured from a given ration are influenced in large part by the amount fed in excess of the maintenance requirements. For economical as well as rapid gains, therefore, some concentrates must be fed. Whether full or limited grain rations are more profitable, all factors considered, is the question to which we will now give our attention.

Full versus limited feeding on forage. Fortunately a number of experiment stations have studied this problem rather comprehensively with the result that certain general conclusions can be drawn. In Table 85 there are brought together the results of 17 comparisons made at the Illinois, Michigan, and Indiana Stations. In each trial one group of pigs was given a full feed of concentrates, *i.e.*, all they would eat, and a comparable group was given a limited feed, both lots being on forage. The pigs which had received the limited rations during the forage season were full-fed during the dry-lot finishing period. In nearly all cases the full-fed pigs received a ration of corn and tankage, fed in the self-feeder; in the Michigan experiments a mixture of equal parts tankage and linseed meal was fed as the supplement. Excepting in the Illinois trials, the limited-fed pigs while on forage received a supplement along with the corn. The limited-fed pigs were fed by hand, during the forage period, in an amount a little more than equal, on the average, to one-half the quantity fed in the other lot. The full-fed pigs consumed 1 pound of tankage with each 12 pounds of corn, while for those fed the limited ration on forage the proportion for the entire period was 1 to 16.

The area of forage provided the limited-fed pigs exceeded that for those full-fed. Spring-farrowed pigs were used in all cases, the initial weight for the different experiments varying from 43 to 69 pounds, with an average of 57. Usually the full-fed pigs had attained market weight by the end of the forage period, late in September, while the limited-fed pigs required about a month's additional time in the dry lot to reach the same weight. Alfalfa was the forage used in nine of the experiments, common red clover in five, and rape in three.

Table 85. Full versus Limited Feeding on Forage, to Full Market Weights *(Average 17 Experiments)*

Rations Fed	*Average Beginning Date and Weight*	*Average Daily Gain*	*Average Finishing Date and Weight*	*Concentrates Required for Each 1 Cwt. Gain*	
		lb.			lb.
Corn and tankage: self-fed entire time	June 21 57 lb.	1.548	Oct. 2 217 lb.	Corn	331.0
				Tankage	28.7
				Total	359.7
Corn and tankage: limited-fed on forage; self-fed in dry lot	June 21 57 lb.	1.160	Nov. 5 215 lb.	Corn	327.0
				Tankage	20.6
				Total	347.6

The pigs fed the full rations during the forage season gained rapidly during the entire feeding period and reached market weight by the end of the grazing season. Those fed half-rations, on the other hand, gained at the rate of 0.75 pound daily while on forage and at the end of the grazing season weighed only 140 pounds, necessitating 33 days of full feeding in the dry lot before reaching the market weight of 215 pounds.

The amount of corn and supplement required for each 100 pounds gain did not vary much in the two methods of feeding, although in all but four of the 17 trials less feed was required by the limited-fed group. The amount of forage eaten by the limited-fed pigs exceeded, of course, that of the full-fed pigs. In some of the experiments the same forage area was allowed in both lots. In most of the cases, however, those fed the restricted rations were given double or more than the full-fed pigs. In those cases where the forage lots were the same, larger cuttings of hay were taken, as a rule, from the lots fed the full rations.

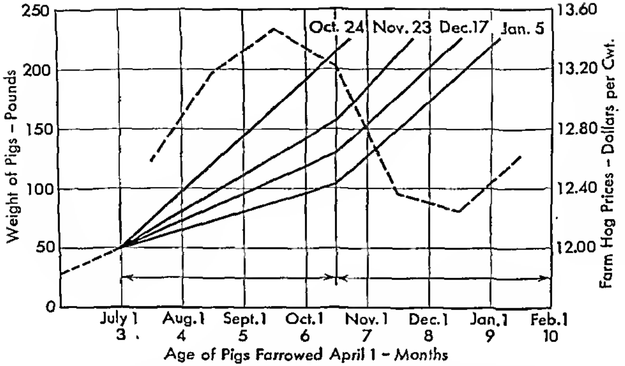


Fig. 46. These graphs show how the feeding of full and limited rations to pigs while on forage affects the time of marketing and length of the dry-lot feeding period. The pigs were farrowed April 1 and the forage period began July 1 when the pigs weighed 50 pounds, and ended October 15. All groups were full-fed during the dry-lot period and marketed at the weight of 225 pounds. Hog prices (broken line) are for the period 1934 to 1949, inclusive.

Full-fed pigs sell high. The fact that the pigs fed the full rations in these experiments were ready for market 33 days earlier than the limited-fed pigs is a matter of considerable practical significance for the reason that the early market is usually the best market. Normally the bulk of the spring-pig crop reaches market in December and January, while the low point in the supply comes in August and September. As the runs increase in autumn and early winter, the price tends to decline. For the period 1930 to 1939 inclusive, as shown in Fig. 73, December hog prices were \$1.40 per hundredweight lower than in September. When the general trend of hog prices is upward, this margin becomes small or may disappear; with a falling market trend, on the other hand, the difference is increased. In the experiments just considered the full-fed pigs were ready for market October 2 and the limited-fed pigs November 5. With the decline in prices which normally occurs during this season, as shown in the graph, it means a serious price handicap for late-marketed pigs. In addition to a higher selling price, early marketing means that the premises and equipment are vacated early for the accommodation of the fall pigs,

the turnover is shorter, and the labor requirements and risk of loss are somewhat reduced.

Limited-fed pigs produced economically. In these experiments there was a saving of 4 pounds of corn and 8 pounds of tankage in the production of each 100 pounds of gain by the limited-feeding method. This is not a large difference. What is more significant is the fact that the corn used in the limited-feeding method was less expensive, as shown in the graph of Fig. 46. The bulk of the corn required in full feeding is fed in the months of August and September, while in the limited-feeding method it is fed mainly in September, October, and November. If the corn is figured on the basis of its price when fed, its cost in the limited-feeding method in these experiments was approximately 5 cents less a bushel than in the full-feeding method. The limited-fed pigs consumed less tankage, but required more forage. Counting 12 pigs to the acre for the limited-fed pigs and 20 to the acre for those fed the full rations, the total cost for the corn, tankage, and forage amounts to 38 cents less for each pig fed the restricted rations while on forage.

Conclusions and discussion. The feeding of full grain rations during the summer while the pigs are on forage has the following advantages as compared with the limited-feeding method:

1. Pigs fed full grain rations sell at better prices. This is because their faster gains enable them to be marketed earlier. The difference in selling price between early- and late-marketed pigs is sufficiently large, as a rule, to warrant giving considerable weight to this point.

2. The earlier marketing of the full-fed pigs also means that the returns are quicker, risk from loss is reduced, labor costs are less, and the farm equipment is made available earlier for the accommodation of the fall pigs.

In favor of the limited-feeding method may be mentioned the following points:

1. The total feed cost of the finished market pig is somewhat less in the limited-feeding method. Although the forage requirements are about one-half greater, the bulk of the corn fed is cheaper in price than in the full-feeding system. Further, the total amount of corn required is no greater (usually it is less) and the quantity of tankage needed is less.

2. Pigs fed limited grain rations during the summer are of a weight and condition at the close of the forage season to make them ideal for hogging-off corn or following cattle later. This is an important

point, for about 6 percent of the corn acreage was harvested in this way in 1946 and 1947, and cattle feeding without hogs to follow usually is not profitable.

Although exceptions are rare to the rule that early-marketed spring pigs sell higher than late-marketed pigs, it is well to keep in mind the fact that this advantage will prevail only so long as the great bulk of the spring-pig crop continues to be marketed in November, December, and January as at present. In other words, the advantage of a better price for the early-marketed pig would disappear if the majority of pork producers were to adopt the practice of full feeding. Because of the scarcity and high price of old corn, however, and the use on many farms of pigs to hog-off corn, follow cattle, or eat kitchen offal, there probably will be no general change made from the system of feeding now employed.

The importance to be attached to the higher price of old corn as an advantage for the limited-feeding method is not great. Very few farmers buy their corn as they feed it; most of them feed only what they grow. Furthermore, in practice those who are short on corn and have to buy are the ones most likely to follow the limited-feeding system. If the corn fed is figured according to its cost of production, plus carrying charge, instead of at the market quotation when fed, the advantage for the system of limited grain rations in economy of the gains practically disappears, since the saving in tankage is more than balanced by the larger forage charge.

It is doubtful if much labor is saved by the full-feeding method. What little is gained through earlier marketing is balanced by the larger demands made by the earlier farrowing season characteristic of the two-litter system and full feeding. For the same reason the equipment necessary for handling the hogs where the full-feeding method is followed is probably greater rather than less than in the limited-feeding plan.

The full-feeding method would appear to be best adapted to those farms which produce both fall and spring pigs and where pork production is the major enterprise of the farm and early-spring farrowing is the rule. Limited feeding is probably the most profitable system for those farms which have a plentiful supply of good forage and where the pigs are farrowed late and produced mainly for the purpose of following cattle, hogging-off corn or other crops in the late fall, or to provide a supply of home-cured pork.

When limited grain feeding is to be practiced, it is important that

it should not begin before the pigs have attained a weight at least of 50 or, better, 75 pounds. From the age of three weeks, when he begins to eat, the pig should be allowed all the concentrates he will take until sufficient development has been reached to ensure his ability to handle forage successfully.

Another important rule to keep in mind when limited rations are fed is never to restrict the grain supply so severely that a gain of at least one-half pound daily is not secured. On excellent forage this gain may be made on one-fourth of a full grain ration, or 1 percent of the live weight daily; under most conditions, however, more than one-third of a full feed will be needed. The quality and abundance of the forage, and the age, thrift, and condition of the pigs should be considered in deciding just how limited the grain supply should be made.

Pigs intended for the breeding herd. The question whether full or limited rations should be fed pigs intended for the breeding herd when on forage is one which practical experience must be largely depended on to answer. Although economy of production is desirable with breeding as with market pigs, the primary object should be to produce a strong well-balanced development which will be most consistent with reliable breeding performance later. As a rule, this object will be best served by rations sufficiently liberal that rapid growth is promoted, yet not so heavy that danger of overfatness and broken-down pasterns is incurred.

Whether full or partially limited rations will be most appropriate in any situation will be influenced by the quality and area of forage available, the type of the pigs, and the advantage of sales which may come from good size and early development. When the forage is abundant and of good quality and when the pigs are of a type which tends more to growth than fat production, the little danger which attends full feeding may be more than balanced by quicker and better sales in the fall and a somewhat larger and more attractive appearance at maturity. Under most conditions it will be best to full-feed until the pigs have reached a weight of 75 to 100 pounds, and from then on to limit the concentrates to three-fourths or two-thirds of a full ration.

FEEDING PROTEIN SUPPLEMENTS

We will now consider the question whether pigs fed corn or other grain on forage should be given in addition a nitrogenous or protein

supplement. In considering the problem it will be found that there are three important factors which affect the results. These are, first, the quality and composition of the forage, particularly its richness in protein; second, whether full or limited grain rations are fed; and third, the age of the pigs.

Composition and yield of forage. That some forages furnish more protein than others and that the same forage varies widely in its protein content at different stages of growth are shown in the analyses presented in Table 64. Also, because of differences in palatability and yield, some forages supply much more protein than others for a given area.

Generally speaking, the legumes as a class are richer in protein, as well as in minerals and vitamins, than the grasses. The dry matter of legumes, as shown in Table 64, contained an average of 21 percent protein, and the nonlegumes 16.8 percent. Legumes, as a rule, also yield heavier and generally are more succulent and palatable. The need for protein supplements for pigs grazing bluegrass, timothy, rye, or other small grain forage will consequently be greater than for those on alfalfa or clover.

Corn with and without a protein supplement. The question of the advisability of feeding a protein supplement with corn to spring pigs running on forage during the summer has been studied experimentally by practically every station in the Corn Belt. The results of 39 such trials have been averaged and presented in Table 86. The averages are significant for the reason that there was close agreement in the results obtained at the different stations, as well as in the duplicate trials of the same investigators.

Only those experiments in which full grain rations were fed are considered here. In each trial spring pigs of an average weight of 53 pounds were used; one lot was fed corn alone and the comparable lot corn with a protein supplement. In the Illinois trials a mixture of two parts tankage to one of soybean oil meal was fed; in eight at Indiana it was equal-parts meat scraps and soybean oil meal. In the other trials it was tankage alone. In most of the experiments the pigs in both lots were fed until market weights were reached. In 19 of the trials the pigs were on alfalfa forage, in 11, on medium red or ladino clover, and in 9 on rape. In most cases the rations were self-fed, free-choice. The amount of supplement eaten in any trial did not vary much from the average of 1 part to 13 parts of corn. The results on the different forages are first summarized separately and then collectively.

Table 86. Corn Alone versus Corn and Supplement, Full-feed, for Pigs on Forage
(Average 39 Experiments)

Rations	*Average Initial Weight*	*Average Daily Gain*	*Concentrates to Produce 1 Cwt. Gain*	
	lb.	lb	lb.	
Corn + clover forage	53	1.31	Corn	360
Corn + supplement + clover forage	53	1.59	Corn	317
			Supplement	25
			Total	342
Corn + alfalfa forage	58	1.23	Corn	368
Corn + supplement + alfalfa forage	58	1.45	Corn	327
			Supplement	24
			Total	351
Corn + rape forage	44	0.93	Corn	368
Corn + supplement + rape forage	44	1.17	Corn	321
			Supplement	28
			Total	349
Average: Corn alone + forage	53	1.18	Corn	366
Average: Corn + supplement + forage	53	1.43	Corn	323
			Supplement	23
			Total	346

[illegible]

The effect of adding a supplement to a full feed of corn on forage was to increase the gains in every single instance. The average difference in rate of gain was one-fourth of a pound daily for each pig. If we assume that the pigs in both lots were fed to the same market weight of 200 pounds, an extra feeding period of 24 days was necessary for those fed corn alone. However, in 10 of the 39 trials the pigs without the supplement made a unit of gain on fewer pounds of total concentrates. On the average, 23 pounds of supplement saved 43 pounds of corn in the production of 100 pounds of gain. A slightly larger area of forage was required by the pigs that received no supplement.

Conclusions and discussion. It would appear from these results that the principal, if not the sole, advantage of feeding a protein supplement with corn to pigs on forage when full rations are given is the result of the faster gains and earlier market finish which it ensures. A difference of 24 days in time of selling fall-marketed pigs will usually mean in favor of pigs fed a protein supplement an important advantage in price, due to the usual price decline which occurs at this season of the year.

The total cost of the gains, figured in dollars and cents, was practically the same in the two methods of feeding. In these experiments the cost of the supplement fed was almost exactly compensated for by the saving which it effected in the amount of corn and forage required.

The benefits to be derived from feeding a protein supplement with corn to pigs on forage will be influenced by the age of the pigs. In the Illinois experiments, which were included in the summary, Carroll found that for each pound of supplement fed after the pigs had passed the weight of 100 pounds, only 1½ pounds of corn were saved, whereas for the period preceding this weight, a pound of supplement had the effect of saving 3½ pounds of corn.

The quality and abundance of the forage also are factors which will influence the results. Naturally, when the forage available is below par, the result of a poor stand, restricted area, or drought, the benefits of a nitrogenous supplement will be much greater than that shown in the above study. Since only high-class forages were used in these experiments and the area available was adequate in all cases, the results as they apply to farm conditions generally tend rather to underrate than overrate the value of protein supplements when full rations are fed.

Wheat and barley with and without a supplement. Similar results have been obtained outside the Corn Belt when wheat or barley was the grain fed. In extensive early experiments conducted by Smith and Maynard of the Utah Station,[4] in which ground wheat or ground barley, self-fed, was supplemented with tankage, liquid skim milk, or skim milk powder for growing and fattening pigs on alfalfa pasture, it was found that the milk products produced considerably faster gains, but that the tankage was of little benefit. Only in the trials where liquid skim milk was fed was there any reduction in the cost of the gains compared with those receiving the grain and salt on alfalfa without a supplement. At the Nevada Station, Headley[5] concluded that the faster gain obtained by self-feeding a protein supplement along with either ground barley or ground wheat, self-fed, for pigs on alfalfa pasture was not significant.

Protein feeding for limited periods. From all these results it appears that when pigs are on a first-class forage from a beginning weight of 50 to 60 pounds up to near market time, that the feeding of a protein supplement during the entire period in addition to a full feed of corn is sometimes profitable and sometimes not, depending chiefly on the price premium received for the earlier marketed pigs and the relative cost of the supplement, as compared with the system of feeding straight corn. Since the needs of the pig for protein decline with advancing age and the extra returns from the supplement fed become less and less as he grows and fattens, the question naturally arises: would not the plan of supplying a supplement during the earlier period of growth and withholding it during the later fattening period be more profitable than either of the plans compared above?

and bone scraps, wheat middlings, and cottonseed meal. The results of this experiment, which was twice repeated, are averaged and presented in Table 87.

Table 87. Showing the Effects of Discontinuing the Protein Supplement at Different Stages of Forage Period
(Average 3 Experiments)

Lot Number	*Supplement fed from 75 lb. to—*	*Days Required to Reach 200 lbs.*	*Average Daily Gain*	*Feed Required for 1 Cwt. Gain*	*Cost 1 Cwt. Gain, Including Pasture*
			lb.	lb.	
I	None	78	1.62	Corn, 329.1 Minerals, 2.4 Total 331.5	$7.11
II	100 lb.	73	1.72	Corn, 320.8 Sup., 8.6 Minerals, 2.1 Total 331.5	$7.15
III	125 lb.	72	1.76	Corn, 314.0 Sup., 17.1 Minerals, 1.3 Total 332.4	$7.25
IV	150 lb.	70	1.81	Corn, 308.7 Sup., 30.1 Minerals, 0.9 Total 339.7	$7.54
V	175 lb.	68	1.86	Corn, 299.3 Sup., 39.5 Minerals, 0.8 Total 339.6	$7.62
VI	200 lb.	67	1.89	Corn, 283.2 Sup., 50.2 Minerals, 0.6 Total 334.0	$7.62

In each of the three experiments the rate of gain increased as the supplement-feeding period lengthened, but not greatly. On the other hand, the amount of concentrate required for a given gain was slightly less in those lots which received the protein supplement only up to 125 pounds or less, than for those which received it for the longer periods. However, the difference is hardly significant. Since the amount of supplement consumed, when available, in relation to corn was

excessive, a somewhat more favorable showing in cost of gains would have been made in those lots which received the supplement for the more extended periods if the protein allowance had been restricted In none of the lots which received the protein supplement was the saving in corn equal to the amount of supplement consumed for the production of a given gain. The extra good gains in Lot I, with no supplement, were the result of the fact that the pigs were thrifty and weighed 75 pounds when the experiments started, and the forage was of first-class quality.

Robison of the Ohio Station [7] also studied the advisability of reducing or eliminating the protein supplement for pigs on good forage during the later periods of growth and fattening. In each of the summers of 1943, 1944, and 1945, one lot of 60-pound pigs was fed the protein concentrate during both the growth (53 to 127 pounds) and the fattening period (127 to 220 pounds), a second similar lot was fed the supplement during the growth period only, while a third group received a reduced amount of supplement during both periods. In the latter group about one-half as much supplement was fed as was given in the first lot.

The average daily rate of gain was 1.50, 1.44, and 1.47 pounds, respectively; the total concentrate required to produce one hundredweight of gain was 378, 385, and 396; and the cost of 100 pounds of gain, including the pasture, was $9.50, $9.48, and $9.73, respectively. The number of days required to reach the market weight of 220 pounds was, respectively, 111, 118, and 116.

It is probably safe to conclude from all the studies that have been reviewed that farmers who follow the two-litter plan of production will usually find it advantageous to continue feeding a protein supplement until the pigs have reached the weight of 125 pounds. Restricted amounts thereafter will be profitable when the forage is not up to standard and particularly when the hog market is tending downward (see Fig. 46, page 276).

braska, Ohio, and Indiana Stations that furnish information on this point, which will now be considered.

In Table 88 are brought together the essential results of 13 such trials. In each comparison there were 10 pigs fed corn alone and a comparable group fed corn with a small amount of tankage. In 12 of the experiments the proportion of corn to tankage in the supplemented ration was 1 to 19, or 5 percent of the ration, and in one trial it amounted to 10 percent of the ration. Practically the same amount of concentrates was fed in the two lots, 1.95 pounds daily per pig in the corn-alone lot and 2 pounds in the corn-tankage lot. This was just slightly more than half of what the pigs could have eaten. Alfalfa was the forage used in eight of the trials, medium red clover in four, and rape in one. In the Indiana experiments 1½ acres of forage was allowed each group of pigs. The average beginning weight of the pigs for the different tests ranged from 44 to 69, with an average of 62. The feeding periods began in late June or early July and continued for periods averaging 77 days.

Fig. 48. Sows and litters on alfalfa. The tender leaf of the alfalfa plant is rich in lime, vitamins, and good-quality proteins, constituents which corn lacks. Under these conditions the sows produce their most abundant milk flow, the pigs are safe from parasites, the losses prior to weaning are reduced to the minimum, and the pigs are at maximum weight and vigor at weaning time *(photo by Allen).*

Conclusions. At the end of the forage period the pigs fed corn alone weighed 117 pounds and those fed corn and tankage 122 pounds. This slight difference in rate of gain is accounted for by the slight

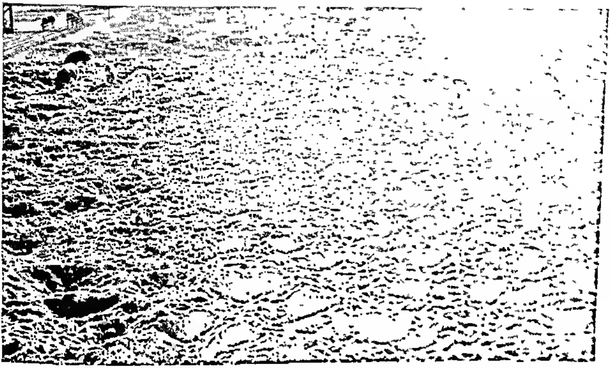
Table 88. Corn Alone versus Corn and Tankage in Limited Rations on Forage
(Average 13 Experiments)

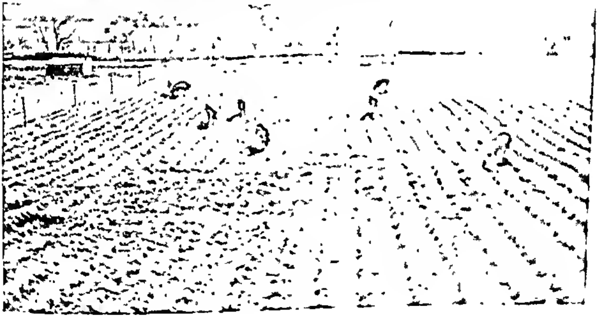
Rations	*Average Initial Weight*	*Average Daily Gain per Pig*	*Concentrates Required for Each 1 Cwt. Gain*	
	lb.	lb.		
Corn, ½ feed + forage	62	0.719	Corn	272
Corn + tankage, ½ feed + forage	62	0.786	Corn	242
			Tankage	14
			Total	256

difference in the daily feed supply allowed the two lots. Each pound of tankage fed had the effect of saving practically 2 pounds of corn. Usually the cost of this feed is more than double that of corn. Since there was little difference in the forage area required, also, and since little if any credit is to be allowed for the 5 pounds extra weight of the tankage-fed pigs at the close of the experiment, the conclusion seems clear that the feeding of a commercial protein supplement like tankage to pigs receiving a limited feed of corn on good forage is not to be recommended.

This conclusion seems reasonable, especially when we consider the purpose the feeder has in mind when the limited-feeding plan is adopted. It is to carry the pigs through the summer as economically as possible and to have them at such weight and condition in the fall that they will be able to perform efficiently the function of cleaning up after cattle or hogging-off corn or other crops. Those fed corn alone on forage will prove better rustlers as a rule than those fed tankage in addition. In the Indiana experiments, Vestal found that the pigs fed corn alone made considerably more economical use of their feed during the subsequent dry-lot finishing period, during which time both groups were full-fed corn and tankage. The amount of concentrates required to produce 100 pounds of gain by those that had received straight corn on forage was 376 pounds, while for those that were fed tankage in addition it was 397 pounds.

FEEDING MINERALS ON FORAGE





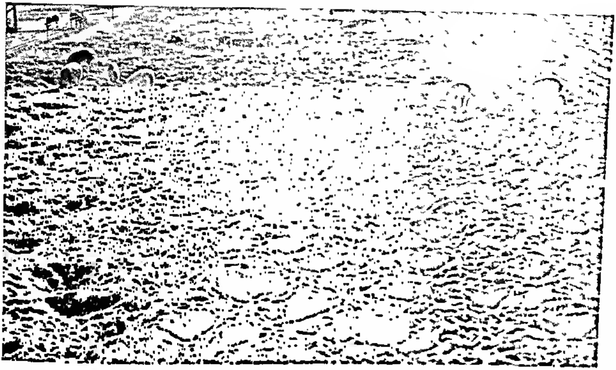
or a mixture of two parts animal with one part plant supplement; (*b*) when a full grain ration is fed with a plant supplement, such as linseed oil meal, middlings, soybeans, or soybean oil meal; and (c) when a full ration of corn alone or other grain is fed without a supplement.

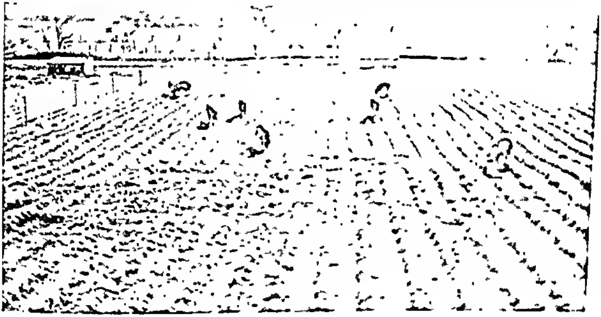
Minerals with an animal supplement. The verdict of the experimental studies made of a mineral feeding under these conditions is quite clear. At the Wisconsin Station Bohstedt [8] fed 130 spring gilts a standard ration composed of corn, oats, and wheat middlings supplemented with a mixture of two parts tankage and one part linseed oil meal, and an equal number of comparable gilts, the same ration with the addition of different minerals or mineral mixtures. They were on forage during the grazing period and received alfalfa hay during the following winter. The figures reported in the table are for the entire period from weaning to farrowing time. The amount of concentrates fed was a little less than full rations, but sufficient to promote rapid growth. In none of the comparisons made in this study did the mineral additions to the ration prove beneficial as judged either by the rate and economy of their gains or the number and strength of pigs produced in the subsequent farrowing season. The concentrate basal ration contained 0.39 percent of calcium and 0.47 percent of phosphorus, as calculated from the tables.

Similar results were secured at the Iowa Station,[9] where one group of spring-farrowed gilts was fed a three-fourths ration of corn and oats with one-third of a pound of tankage daily for each gilt, on either bluegrass, alfalfa, clover, alsike, sweet clover, or rape forage, and another similar group the same ration fed on the same forage, but with the addition of a complex mineral mixture composed mainly of salt, bone black, wood ashes, and limestone. In none of the six pairs of lots fed in this experiment was there a significant difference in the rate or cost of gains favorable to the pigs which received the mineral mixture, although a slight difference favored the mineral-fed pigs which were on bluegrass.

In three experiments at the Illinois Station [10] the feeding of a variety of minerals, including coal and charcoal, free-choice, or a mineral mixture self-fed, on rape or bluegrass, did not prove profitable. The results in rate and economy of gains were practically identical with those obtained with the same rations without the minerals. The

[8] G. Bohstedt, *Proc., Am. Soc. An. Prod.*, Nov., 1930.
[9] John M. Evvard, C. C. Culbertson, and W. E. Hammond, *An. Proc., Am. Soc. An. Prod.*, Dec., 1922.
[10] J. B. Rice and H. H. Mitchell, Bul. 250. 1924.





the trials where the minerals were fed separately in different compartments of the self-feeder, the consumption of coal amounted considerably to more than all the other minerals combined. However, the other minerals, excepting common salt, were eaten only in traces.

Anderson and associates at the Iowa Station [11] found, according to the results of three experiments covering the grazing period, that nothing of a practical nature was to be gained by feeding sodium bicarbonate at different levels to growing pigs on bluegrass, rape, or alfalfa pasture and by receiving a ration of corn and oats supplemented liberally with a mixture made up of two parts tankage, one part linseed meal, and one part alfalfa meal.

One experiment with full-fed pigs, fed corn and tankage on a mixed legume pasture at the Ohio Station [12] gave no conclusive evidence that it was necessary to feed a mineral mixture, the slight difference in favor of the mineral-fed pigs not being large enough to be significant. If the results of this and the other trials are brought together, the averages will be as shown in Table 89.

Table 89. Minerals versus No Minerals with Animal Supplements on Forage *(Average 23 Experiments)*

Rations	*Initial Weight*	*Daily Gains*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	
Full or ¾ full grain + animal supplement, without minerals	50	1.026	Grain	473
			Supplement	29
Full or ¾ full grain + animal supplement, with minerals	50	0.993	Grain	481
			Supplement	30
			Minerals	9

These results are logical when one considers the mineral composition of animal supplements and good green forage. Both are rich in calcium or lime, and when either alone is available with corn, the supply is above the minimum requirements (see Table 44). When both sources are available, as they were in these test rations, there is no need of further insurance that the mineral requirements will be satisfied.

Mineral feeding with plant supplements. Reference to Table 44 will show that the animal protein supplements, tankage, fish meal,

[11] A. L. Anderson, C. C. Culbertson, John M. Evvard, and W. E. Hammond, *Proc., Am. Soc. An. Prod.*, Nov., 1932.

[12] W. L. Robison, Spl. Cir. 26, 1929.

and the milk by-products contain many times the amount of calcium or lime as the plant supplements, linseed meal, soybeans, soybean oil meal, cottonseed meal, or wheat middlings. When any of the plant supplements are fed with corn or other grains on forage, therefore, there is some reason for believing that mineral feeding might be advisable, especially when the forage is below average quality. The experimental studies which have been made of this problem give results which are in close agreement with one another and with this expectation.

The Iowa, Ohio, Illinois, and Indiana Stations have made studies in which the feeding of minerals, including salt, along with a full feed of corn or other grain and a plant supplement on good forage, was compared with the same ration on forage without minerals. Twenty-two such comparisons were made, the average results of which are shown in Table 90.

Table 90. Minerals versus No Minerals with Plant Supplements on Forage
(Average 22 Experiments)

Rations	*Average Initial Weight*	*Average Daily Gain*	*Average Feed Required Each 1 Cwt. Gain*	
	lb.	lb.		lb.
Grain + plant sup. + forage	60	1.216	Grain	400
			Sup.	37
Grain + plant sup. + minerals			Grain	350
+ forage	60	1.382	Sup.	31
			Minerals	2.79

The showing made by minerals when fed under these conditions of feeding will, of course, be influenced a good deal by the quality and kind of forage available. The appropriateness of the minerals fed will also be a factor. The effect of a mineral addition to a full grain ration balanced with a protein supplement of plant origin will be much less when the forage is a good legume than when bluegrass or timothy pasture is used; with any of the forages its value will be much enhanced when the season is droughty or otherwise unfavorable. These results, however, suggest that in any of these situations the feeding of minerals rich in calcium and common salt will be profitable.

logical to believe that it would be beneficial with corn alone, since the plant supplements, excepting shorts and middlings, contain many times more of calcium than does corn. On the other hand, pigs getting corn alone will eat more forage which, on the dry-matter basis, is much richer in minerals, especially the much-needed calcium, than the plant supplements. Although experimental study of the question has been limited, the evidence available is slightly in favor of mineral feeding under these conditions.

Experiments have been conducted at the Ohio, Iowa, and Indiana Stations in which spring pigs averaging in weight from 50 to 60 pounds at the start were full-fed a ration of corn alone on either rape, mixed legumes, clover, or alfalfa forage in contrast with comparable pigs fed the same rations and forage but with a mineral mixture rich in calcium in addition. Both lots had salt available. The results of the five trials made at the Indiana Station, which are summarized in Table 91, represent fairly those obtained at the other stations.

Table 91. Minerals with Corn Alone on Legume Pasture
(Average 5 Experiments)

Rations	*Average Initial Weight*	*Average Daily Gain*	*Average Feed to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.	
Shelled corn, self-fed, + legume forage	70	1.30	Corn	338
Shelled corn, self-fed, + mineral mixture, self-fed, + legume forage	70	1.45	Corn Mineral mixture	331 5.4

In each of the trials, excepting one, the rate of gain was faster in the mineral-fed lot, the average increase being 11.5 percent. In producing gains, each pound of the mineral mixture eaten had the effect of saving, on the average, 1.3 pounds of corn; in two of the trials, however, the feed cost was increased by the minerals. The amount of the mineral mixture consumed represented 1.6 percent of the ration.

In only three of the seven trials reviewed was the difference in rate of gain significant; yet in all excepting one, in which it was the same, the pigs fed the mineral mixture in addition to common salt made the faster gains. The results, no doubt, would have been more favorable to mineral feeding if no salt had been fed in the "no-mineral" lot.

In conclusion it may be stated that, although the evidence is not conclusive, the feeding of a suitable mineral mixture under these conditions will not be out of line with good practice. Especially will this be true when the pigs are below 100 pounds in weight and when the forage is a nonlegume or when for any reason its quality is below par. When the pigs are restricted to a limited feed of corn on good forage, however, one would suppose mineral feeding, excepting possibly salt, to be quite unnecessary, especially for the older pigs.

Suitable mineral mixtures. There appears to be no clear evidence that any minerals in addition to calcium and common salt are needed to supplement the usual rations fed growing and fattening pigs on forage. When such supplements are needed, the following simple mixtures supply the necessary elements in the proportions believed to be most nearly ideal.

Number 1

1 part finely ground limestone
1 part steamed bone meal
1 part common salt, or iodized salt

Number 2

1 part steamed bone meal
1 part defluorinated ground rock phosphate
1 part common salt, or iodized salt

Number 3

1 part hardwood ashes
1 part air-slacked lime
1 part common salt, or iodized salt

Number 4

1 part finely ground limestone
1 part hardwood ashes
1 part common salt, or iodized salt

Other commercial sources of calcium available are ground oyster shells, marl, calcium carbonate, precipitated chalk, and di- or tricalcium phosphate.

Probably the best way to feed minerals in practice is to mix the essential ingredients and self-feed in a separate compartment of the feeder, or in a special mineral-feeder box. When the salt is fed as one-fifth instead of one-third of the simple mixture, as is often the case, it is considered desirable to give the pigs access to an additional supply in another compartment.

CARE AND MANAGEMENT IN THE FIELD

Two indispensable factors in the successful management of pigs during the summer are plenty of shade and a good water supply. Without these they will not do well even with the best of rations.

A regular supply of fresh water, easily accessible, is essential because the pig drinks much and often. Large quantities are needed to maintain good nutrition and to help keep down his temperature during

the heat of midsummer. Since he cannot sweat, a scarcity of water when the heat is excessive may result fatally. It is advisable to locate portable fountains in the shade, convenient to the feeders, and as close as possible to the place where the pigs lay during the heat of the day. The normal water requirements of pigs are shown in Table 50.

Plenty of shade is almost as important as good water. The shade of trees is preferable to all others, but trees are usually not found in forage fields. Without natural shade, dependence must be placed on the individual farrowing houses, which have been so constructed that the sides open out, supplemented with a specially constructed shade made with six to eight posts, some old rails, and a few two-by-fours, and roofed with straw or hay.

Hog wallows are valuable. The studies of Heitman and Hughes of the California Station (see page 134) showed that as the temperature increased above 75°F the rate of gain of pigs weighing from 70 to 144 pounds declined and the feed required for a unit of gain increased. At the Texas Station Jackson [13] found that at temperatures above 83°F hogs having access to concrete-constructed wallows ate more feed and gained faster and more economically than those without a wallow. Artificially constructed wallows may not be practical for pigs on forage in the North, but their more general use in the South would help to reduce losses from heat prostration and promote more efficient feeding results.

Wallows also provide an efficient means of combating external parasites. For example, by adding a disinfectant to the water in an amount to give a concentration of about 2 percent, or by covering the water with a thick film of crude oil, it will prove an effective method of ridding the hogs of lice.

THE GRAZING HABITS OF PIGS

Below are given some observations on the grazing habits of pigs by Shepperd and herdsman Geiken of the North Dakota Station.[14] The knowledge gained through such systematic observations is valuable because without it the most intelligent care and management are not possible. The quotations are based on observations taken of two groups of spring pigs, numbering 82 and 72, during the seasons of 1926 and 1928.

[13] A. D. Jackson, Progress Rpt., 1948.
[14] Bul. 230, 1929.

Pigs start out for their day's foraging from sunrise to a half-hour before sun up, varying with the degree of heat which they must endure.

They lay up in the middle of the day a varying length of time depending upon the temperature, food supply, and the distance they must go from home to forage.

When the heat mounted to 90°F on August 26, 1926, they slept and loafed from 9:15 A.M. until 3:45 P.M.—to the last pig—a period of six and a half hours.

On October 8 of the same season with the maximum temperature 72°F at no single time during the day did all the pigs lay up at once.

On that day—October 8—daylight set them back to a 6:30 A.M. start and apparently caused them to bed down for the night at 5:45 P.M., which gave them a much shorter day than they had in July.

On July 9, 1928, with a maximum temperature of 71°F their beginning hour was 5:30 A.M. and their quitting time 9:15 P.M. On that date the temperature was cool, similar to that of October 8, 1926, and only an hour and three-quarters of complete rest for the entire 72 head occurred. The rest period was taken from 1:00 to 2:45 P.M.

XI *Hogging-off Corn and Other Crops*

The practice of turning pigs into the cornfield when the grain is well dented and allowing them to remain to harvest the crop, known as "hogging-down" or "hogging-off," is quite general. In 1946 and 1947, 5.84 percent of the corn acreage in the United States was harvested by this method.

For the latitude of the Corn Belt, the hogging-off season begins about October 1 and ends 30 or 40 days later. Usually the weather is not favorable for a longer season, although occasionally early fall pigs are kept in the field until Christmas. Late-farrowing spring pigs that have received a limited grain ration during the summer, which are thin, active, and of a weight from 90 to 140 pounds, are the kind most efficient for this practice.

The acreage of corn which is hogged-off annually varies quite widely in the different states and areas. In general, the practice is more common in the North than in the South. In the five Corn Belt states, Iowa, Illinois, Indiana, Ohio, and Missouri, an average of a little less than 3 percent of the acreage was hogged-off in 1946 and 1947.[1] In Minnesota, Wisconsin, and Michigan an average of 9.6 percent was harvested by this method. For the United States as a whole, 5.84 percent was hogged-off during these years; prior to 1936 the reported figure was 11 percent.

HOGGING-OFF AND YARD-FEEDING COMPARED

Results of experimental studies. There are many hogmen who look on the practice of harvesting corn with hogs as wasteful; there are many others, on the other hand, who consider it efficient as well as labor-saving. We will consider now the results which have been obtained when the question of the profitableness of this method of feeding corn is subjected to experimental tests. Such studies have been

[1] *Agricultural Statistics*, U.S.D.A., 1948.

made at five different stations (Iowa, Indiana, Minnesota, Kansas, and Ohio).

In all of these trials one group of pigs was confined in the yard or dry lot and fed by hand or self-feeder and another comparable group placed in the cornfield with a fenced area which could be cleaned up in 30 or 40 days. The pigs in the dry lot were given the fresh-husked earn corn, full-feed, from an equal area. The actual yield of the area to be hogged-down was determined by husking out typical rows. In 11 of the experiments, the results of which are summarized in Table 92, both lots were fed tankage, usually in a self-feeder.

Table 92. Hogging-off versus Yard-Feeding
(Average 17 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain* [a]		*Pork Produced for Each Bushel Corn Fed* [a]
	lb.	lb.	lb.		lb.
Yard-fed, corn + tankage	118	1.745	Corn Tankage	398 30	14.1
Hogging-off, corn + tankage	118	1.645	Corn Tankage	444 30	12.6
Yard-fed, corn + tankage	128	2.036	Corn Tankage	377 18	14.8
Hogging-off, corn + tankage + forage	128	1.885	Corn Tankage	422 20	13.3
Average yard-fed	121	1.848	Corn Tankage	391 26	14.3
Average hogging-off	121	1.730	Corn Tankage	436 27	12.8

[a] Calculations based on a moisture content of 14 or 15½ percent.

In a few of the trials minerals also were fed. In six of the tests the pigs in both lots, in addition to receiving corn and tankage, had access to rape or other green feed. The rape for the pigs in the standing corn was seeded in the corn at the time of the last cultivation in three of the trials; in the other three the forage was separate but adjacent to the field being hogged-off. The results of these six trials are summarized separately in the table. The pigs at the beginning of the different trials varied in weight from 69 to 167 pounds and averaged 121. The average beginning date was October 1 and the feeding period 37 days.

Fig. 50. Hogging-off corn. A satisfactory temporary fence, suitable portable shelters, and a good class of pigs for the job (*photo by Allen*).

Very satisfactory gains were made in both lots, with a difference only of 6.8 percent in favor of the pigs fed in the yard. At the finish of the experiments the yard-fed pigs were 4 pounds heavier than those in the field. A feeding period of 10 to 30 days following the close of the experiments was required in most instances to bring the pigs to a market weight of 200 to 225 pounds. In six of the 17 trials the pigs in the cornfield made the faster gains; in 10 of the trials the yard-fed pigs gained faster, and in one both groups made the same gains. In nearly all cases the yard-fed pigs used their feed more completely or economically in producing gains in weight. In only three of the experiments did the pigs in the standing corn make as efficient use of their corn. The difference, on the average, amounted to 1.5 pounds of pork for each bushel of corn fed. The consumption of tankage was practically the same in the two lots.

Cost of harvesting corn. The mechanical harvesting of corn has almost completely replaced the old hand-picking method. The result has been a great reduction in labor costs, but with some increase in the amount of grain left in the field. Barger of the Iowa Station found that this loss varied from 2 to 25 percent.

The costs vary widely, depending chiefly on the yield of corn and the acreage harvested. Based on the recent studies which have been

made at the Pennsylvania,[2] Indiana,[3] and Iowa Stations [4] it appears that the average figure of 12 cents a bushel best represents the total costs of harvesting and cribbing under present conditions.

Advantages and disadvantages of hogging-off corn. In favor of the practice of hogging-off corn may be listed the following advantages:

1. It saves all the costs normally involved in harvesting, cribbing, and feeding. Recent studies indicate that the cost from stalk to crib, with modern machinery, averages around 12 cents a bushel.

2. Hogs in the cornfield leave their manure where succeeding crops will receive full benefit from the fertility contained. In dry-lot feeding the manure must be hauled and much of it never reaches the field.

3. The sanitary conditions in the field are usually superior to those in the dry lot. As a result of their more active life and more vigorous condition, also, field-fed pigs usually will outgain those fed in the yard during the subsequent short finishing period.

4. Hogging-off would appear to have a special advantage over the machine method of harvesting when the corn is badly lodged as the result of wind or corn borer damage.

There are a number of disadvantages that attend the hogging-off method, which may be enumerated as follows:

1. A considerable amount of corn is lost by being tramped into the ground. In a season of light rainfall this loss is probably not much more than is wasted in dry-lot feeding. In a wet season, on the other hand, it may be large. However, this loss probably is less than that which results in shelling and ear losses when the mechanical picker is used. According to Indiana surveys this amounts to an average of around 9 percent. But since such fields usually are later gleaned by hogs or other stock, it cannot be credited to the hogging-down method.

2. Extra fencing is usually necessitated by the hogging-off practice. Although of a temporary character, it represents some cost in time and money. There is also the necessity of moving houses or erecting temporary shelters, and of providing watering facilities and a self-feeder for the supplements.

3. The trampling and packing to which the field is subjected has the effect, in a wet season, of puddling the soil and injuring its tilth for

[2] W. E. Keepper, and S. A. Dunn, Bul. [illegible], 194[illegible].
[3] F. H. Demaree, and R. H. [illegible], Agr. Ext. Service, Purdue University, [illegible]
[4] E. L. Barger, Information to the author, 195[illegible].

future crops. This is especially true of heavy soils. Also, the stover is largely destroyed as winter feed for cattle.

4. The practice of hogging-down corn may at times interfere with the common cropping system in the winter wheat areas of the Corn Belt, since much of the wheat grown in the Corn Belt follows corn in the rotation.

5. The practice results in having the pigs ready for market at a time when the price is usually low and encourages the feeding of limited rations during the summer to pigs that might more profitably have been fed for an earlier market.

PROTEIN SUPPLEMENTS FOR STANDING CORN

In the experiments just reviewed in which the results from hogging-off and yard-feeding were contrasted, both rations included a protein supplement. Without such supplement neither method of feeding would have been profitable. Although pigs used for hogging-off corn are partly grown and will thrive on corn alone for a longer period than younger pigs, it has been clearly proved many times that pigs in standing corn are in as great a need of a nitrogenous or protein supplement as are those fed in the dry lot.

Standing corn with and without tankage. There is abundant experimental evidence to support this conclusion. In Table 93 are brought together the results of 13 such tests made at the Minnesota, Iowa, Nebraska, and Missouri Stations. In each experiment one lot of pigs had standing corn alone while another comparable group in standing corn had in addition tankage supplied in a self-feeder. In six of the trials a mineral mixture was self-fed to both lots. The pigs went into the cornfield on dates for the different experiments, ranging from

Table 93. Standing Corn with and without Tankage
(Average 13 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*		*Pork Produced from 1 Acre of 40 Bushels*[a]
	lb.	lb.	lb.		lb.
Standing corn +			Corn	437	
tankage	109	1.686	Tankage	37	512
Standing corn	109	1.109	Corn	673	332

[a] Corn was reduced to a moisture content of 14 or 15½ per cent in these calculations.

September 7 to October 6, and of an average weight of 109 pounds, and remained for an average period of 38 days. In all cases a short dry-lot finishing period subsequent to the experimental period was necessary, even for the lots which had received tankage.

Not only were the pigs fed the supplement 22 pounds heavier at the close of the hogging-off period, but the increased return for each bushel of corn fed amounted to 4.5 pounds of pork. Each pound of tankage eaten had the effect of saving 6.4 pounds of corn. An acre of corn yielding 40 bushels, according to these results, would produce 512 pounds of pork when supplemented with 189 pounds of tankage, and only 332 pounds when no supplement is fed.

Tankage and soybeans compared. Animal supplements, such as tankage, meat scraps, fish meal, shrimp meal, and the milk by-products, have generally been proved superior to the plant supplements in supplying the deficiencies of corn for pigs. In one experiment at the Michigan Station and two at the Iowa Station whole soybeans, self-fed, were compared with tankage, self-fed for pigs hogging-off corn. A mineral mixture also was self-fed to both lots in the Iowa experiments. In each trial the tankage-fed pigs gained faster, the average being 1.754 and 1.380 pounds daily, respectively, in the two lots, and less total feed was required in the production of a given gain. Each pound of tankage consumed had a value equal to 5 pounds of the beans.

SUPPLEMENTAL CROPS GROWN IN CORN

Farmers who practice the hogging-off method of finishing late spring pigs very often grow a supplementary crop in with the corn. The idea behind this is to increase the pork-producing capacity of an acre and to provide a cheap supplement which will make less necessary the purchase of high-priced protein feeds. The crops which are used most extensively for this purpose are soybeans, rape, and rye.

Soybeans planted in corn. The combination of corn and soybeans should be more efficient as a crop for hogging-off than is standing corn alone. When seeded in the hill or drilled with the corn, the yield of beans and corn will be about in the ratio of 1 bushel of beans to 8 of corn. Although lacking in minerals, the ration is nearly balanced from the standpoint of its protein supply.

Feeding trials have been carried on at three experiment stations, Minnesota, Iowa, and Missouri, to determine the value of this combination in comparison with standing corn alone, the results of which are shown in Table 94.

Table 94. Standing Corn versus Standing Corn and Soybeans
(Average 7 Experiments)

Rations	*Daily Gain*	*Feed to Produce 1 Cwt. Gain*		*Pork Produced from 1 Acre*[a]
	lb.	lb.		lb.
Standing corn	1.057	Corn	692	323
Standing corn + soybeans		Corn	537	
in corn	1.240	Soybeans	70	369

[a] Assuming a yield of 40 bushels of corn to the acre for the corn-alone lot and the same yield of corn and beans, in pounds, in the corn-soybean lot.

In all except two of the trials the pigs hogging-off both corn and beans made the faster gains, and in all but one required less feed to produce a given gain. Minerals were fed to both groups of pigs in only two of the seven experiments, which may have been responsible for the fact that the contrast in the results was not wider. If we assume that the yield of corn and beans together was the same as the yield of corn when grown alone, the beans should be credited with producing 46 extra pounds of pork to the acre. This cannot be regarded as a very favorable showing for the practice of seeding soybeans in with corn that is to be hogged off.

Tankage improves corn and soybeans. The question whether the combination of corn and soybeans for hogging-off can be economically improved by feeding an animal supplement like tankage has been quite definitely answered by experiments conducted at the Missouri, Iowa, and Ohio Stations. The results of these trials, 11 in number, have been averaged and are shown in Table 95. In each of these trials one group of pigs had corn containing soybeans, and a second, similar group had the same with tankage in addition. The tankage was self-fed in all except the Ohio trials, where it was hand-fed in an amount a little more than equal to one-third of a pound daily for each pig. Minerals were fed in three of the trials only. The pigs weighed 125 pounds at the beginning of the hogging-off period, which lasted 31 days for the pigs receiving tankage and a day or two longer for those not receiving tankage.

The individual experiments consistently gave results which paralleled the averages shown in the summary table. In every trial the tankage had the effect of stimulating the appetite and increasing feed consumption and the rate of gain. The gains also were more economi-

Table 95. Standing Corn and Soybeans with and without Tankage
(Average 11 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain* [a]		*Pork Produced from 1 Acre*
	lb.	lb.	lb.		lb.
Standing corn + soybeans in corn	125	1.242	Corn and beans	620	361
Standing corn + soybeans in corn + tankage	125	1.790	Corn and beans Tankage	421 27	532

[a] Assuming a yield of corn and beans together of 40 bushels to the acre.

cal, judged either by the pounds of feed required or in dollars-and-cents cost. The 171 extra pounds of pork produced to the acre were secured at a cost only of 144 pounds of tankage.

Standing corn alone with tankage. That soybeans grown in corn are not so effective in balancing the corn as is tankage is shown by the results of fourteen comparisons made in experiments conducted at the Iowa, Missouri, Ohio, Michigan, and Kentucky Stations which are summarized in Table 96. In each of these trials one group of pigs averaging 126 pounds in weight was given standing corn containing soybeans, and another comparable group was given an equal area of standing corn not containing beans, and tankage fed by hand or in the self-feeder. In seven of the experiments a mineral was fed in both lots.

Table 96. Tankage versus Soybeans in Corn
(Average 14 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required to Produce 1 Cwt Gain*		*Pork Produced from 1 Acre* [a]
	lb.	lb.	lb.		lb.
Standing corn + tankage	128	1.711	Corn Tankage	442 28	[illegible]
Standing corn + soybeans in corn	128	1.291	Corn and beans	[illegible]	[illegible]

[a] Assuming a yield of 40 bushels of corn alone or of corn and [illegible] to the acre.

in the experiments where minerals were fed in both lots. The difference of 138 pounds of pork produced to the acre was secured by the consumption of 142 pounds of tankage. Thus as a supplement to standing corn tankage appears to be much superior to soybeans grown in with the corn.

The question naturally arises at this point whether the combination crop of corn and soybeans will give larger returns when hogged-off than an equal area of corn alone, hogged-off, when tankage is fed in both lots. This particular question has been the subject of experimental study at four different stations, at Minnesota, Iowa, Missouri, and Ohio, the summarized results of which are given in Table 97. The studies represent 12 direct comparisons. The pigs weighed an average of 122 pounds at the beginning of the grazing period, which lasted about 30 days. In all but four of the trials the tankage was self-fed in a convenient location.

Table 97. Standing Corn and Tankage versus Standing Corn with Soybeans and Tankage
(Average 12 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required to Produce 1 Cwt. Gain*		*Pork Produced from 1 Acre* *
	lb.	lb.	lb.		lb.
Standing corn +			Corn	422	
tankage	122	1.778	Tankage	32	531
Standing corn with			Corn and		
soybeans +			soybeans	414	541
tankage	122	1.758	Tankage	29	

* Assuming a yield of 40 bushels of corn to the acre in the corn-alone field and the same combined yield of corn and beans in the corn-soybean field.

The results are not clearly in favor of either method of feeding. In six of the trials the rate of gain was in favor of the pigs in the corn without soybeans, in four it was in favor of the corn-soybean pigs, and in two there was no difference. The average difference is not significant. There was slightly less feed required to produce a given gain in the field containing the beans. If we assume that the tonnage of feed produced was the same in the two cases, then the soybeans must be given credit for producing 10 extra pounds of pork to the acre and with a saving of 13 pounds of tankage. These two items are hardly more than sufficient to pay for the seed and cost of planting the beans.

At the Minnesota Substation, Crookston, Kiser compared the method of planting soybeans alongside of corn that was to be hogged-off with that of the more common practice of drilling them in with the corn. One-third of an acre of beans was planted in rows adjacent to two-thirds of an acre of corn. This plot was compared with an acre of corn and beans planted together. Two comparable groups of 90-pound pigs, numbering eight each, were turned in September 15 and remained in the fields until they were cleaned up 52 days later. The pigs grazing the corn and beans grown separately gained at the rate of 1.48 pounds daily, while those on the acre where they were grown together gained 1.40 pounds daily. The total amount of corn and beans required to produce 100 pounds of gain was 463 and 555 pounds, respectively. According to these figures the acre of corn and beans grown separately produced 615 pounds of pork while the acre containing the two grown together produced 582 pounds.

Barnett and Goodell of the Mississippi Station, from the record of five years' experience in hogging-off corn and soybeans, concluded that the practice of growing them together is more economical and produces more feeding value than either grown alone. They recommend further that when the two are grown together, the corn be husked and fed by hand in amounts up to 2 to 2½ percent of the weight daily while the beans are being grazed. When grazed together, because of the greater palatability of the corn, the corn supply is exhausted some time before the beans are all eaten.

The effect of growing soybeans in corn on the yield of corn. Contrary to the view of many, soybeans planted in corn do not increase the yield of corn; in fact, the effect uniformly is to reduce the yield. Not only that, but the production of beans, in checked planting at least, is not sufficient to compensate for the loss of corn which it causes. When drilled, the yield of both beans and corn is practically the same as the yield of corn alone. These conclusions are based on results obtained at the Kentucky, Missouri, Iowa, Illinois and Ohio experiment stations, where the question was systematically investigated for periods varying from two to nine years at the different stations. The data from these experiments, as compiled by Rob[illegible] are given in Table 98.

Table 98. Showing Influence of Soybeans in Corn, Checked and Drilled, on the Yield of Corn and Beans

Checked in Corn Hill, 2–4 Seeds	*Years' Work*	*Yield per Acre* — *Corn Only*	*Corn Containing Soybeans* — *Corn*	*Corn Containing Soybeans* — *Soybeans*	*Reduction in Yield of Corn*	*Gain or Loss (—) in Total Yield*
	No.	bu.	bu.	bu.	bu.	lb.
E. J. Kinney, Ky. Exp. Sta.	6	45.5	39.8	3.5	5.7	—109
Etheridge and Helm, Mo. Bul. 220	5	42.2	35.2	3.9	7.0	—157
Etheridge and Helm, Mo. Bul. 220	5	38.2	30.3	4.3	7.9	—185
F. S. Wilkins, Ia. Exp. Sta.	9	54.5	45.9	4.6	8.6	—207
R. W. Stark, Ill. Exp. Sta.	2	58.0	51.3	5.4	6.7	—51
Average		47.7	40.5	4.3	7.2	—142
Drilled with the Corn						
F. S. Wilkins, Ia. Exp. Sta.	3	52.5	47.7	5.5	4.8	37
R. W. Stark, Ill. Exp. Sta.	2	53.9	47.0	6.3	6.9	—8
Etheridge and Helm, Mo. Bul. 220	3	45.1	41.1	6.1	4.0	140
J. B. Park, Ohio State Univ.	7	53.4	45.0	7.1	8.3	—41
Agronomy Dept. Ohio Exp. Sta.	1	65.8	56.8	8.2	9.0	—14
Average		52.5	45.8	6.5	6.7	14

profitable one in the Corn Belt when the other usual sources of protein supplements are available. A more favorable showing for the beans would have been made, however, if a suitable mineral mixture had been fed in all cases.

Sowing rape in corn. Dwarf Essex rape is easily the most popular of the supplementary crops grown in corn, especially in the northern half of the Corn Belt.

As reported by Evvard and associates of the Iowa Station, 80 percent of the Iowa farmers who grew such crops preferred rape, 15 percent grew rye, 14 percent pumpkins, and a small number either cowpeas, soybeans, or clover. The usual method of seeding rape is to broadcast it at the rate of about 3 pounds to the acre, at the time of last cultivation. In a season of adequate rainfall it will make a good growth; in a droughty season, however, the growth will be sparse.

From two years' observations, Robison of the Ohio Station concluded that rape in corn will not reduce the yield of corn by more than ½ bushel to the acre, on the average.

One of the important advantages of rape as a supplementary crop in corn is its ease of seeding and low cost of production. In Table 99 the cost of growing rape and other crops, as determined by a study, undertaken 20 years ago and covering several years, at the Iowa Station, is shown.

Table 99. Acre Cost of Growing Corn Supplements

Crops	*When Planted*	*Rate of Seeding*	*Cost of Seed*	*Cost of Seeding*	*Total Cost*
		lb.	dollar	dollar	dollar
Dwarf Essex rape	Last cultivation	3	0.24	0.16	0.40
Rape and pumpkins	Rape, last cultivation; pumpkins, after corn is up	3 1	Rape 0.24 Pumpkins 0.35	0.41	1.00
Rye	Drilled in after last cultivation	136	2.73	0.60	3.33
Soybeans	Drilled in corn row at corn planting time	45	2.73	0.60	3.33
Cowpeas	"	45	2.73	0.60	3.33
Canadian field peas	Drilled, corn planting time	60	3.00	0.60	3.60

Rape compared with soybeans. The feeding value of rape when grown in the cornfield, as compared with soybeans, has been studied experimentally at the Iowa, Ohio, and Michigan Stations. The results of eight such trials are shown in Table 100. In four of the experiments, summarized separately, no supplement in addition to the two crops was provided; in the other four, tankage was fed in both lots.

Table 100. Rape versus Soybeans in Corn
(Average 8 Experiments, 4 Each)

Rations	*Initial Weight*	*Daily Gain*	*Concentrates Required for 1 Cwt. Gain*		*Pork from 1 Acre* [a]
	lb.	lb.	lb.		lb.
Standing corn and rape	149	1.369	Corn Mineral	590 1.07	379
Standing corn and soybeans	150	1.291	Corn and beans Mineral	544 1.85	411
Standing corn and rape + tankage	136	1.665	Corn Tankage	441 24	508
Standing corn and soybeans + tankage	137	1.730	Corn and beans Tankage	407 21	550

[a] Assuming a yield of 40 bushels of corn to the acre when grown with rape and the same total yield of corn and beans when grown with beans.

is fed and 42 pounds when tankage is fed. When consideration is given to the higher cost of seeding soybeans as compared with rape, these two crops would appear to have about equal value on those farms that can grow both equally well.

Rape compared with rye. Rye has given fairly satisfactory results when sown with corn that is to be hogged-off. In a hogging-off experiment at the Iowa Station one group of 15 pigs was given standing corn containing rape which had been seeded in the corn hills at the rate of 1½ pounds to the acre, and another similar group was given the same area of standing corn in which had been seeded rye broadcast at the rate of 60 pounds to the acre after the last cultivation of the corn. The rate of gain was 1.73 pounds daily for the pigs in the field containing rape and 1.57 pounds for the pigs in the rye field. The amount of pork credited to each acre was calculated to be 516 and 503 pounds, respectively. Rye requires more moisture than rape and is believed to affect more seriously the yield of the corn.

Supplemental crops adjacent to corn. Pigs hogging-off corn will do better, as a rule, when some green feed is available because of their succulence, protein content, and the generally stimulating effects. This is shown by the results of two experiments made at the Ohio Station, the results of which are averaged in Table 101. In each trial both groups of pigs had standing corn and tankage. The first year one of the groups had access to clover pasture, in addition, and in the second year a mixture of clover and timothy, mostly timothy.

Table 101. Showing Value of Pasture with Standing Corn
(Average 2 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Concentrates Required Each 1 Cwt. Gain*		*Pork Produced by 1 Acre of Corn*[a]
	lb.	lb.	lb.		lb.
Standing corn + tankage + clover and timothy	101	1.99	Corn	347	645
			Tankage	12	
Standing corn + tankage	101	1.78	Corn	384	583
			Tankage	21	

[a] Assuming a yield of 40 bushels of corn to the acre.

The pigs which had access to the pasture had better appetites, gained considerably faster, and required less feed for a given gain. The forage consumed, the area of which was not stated, had the effect of increasing the amount of pork produced on an acre of standing corn with tankage by 62 pounds. With this gain in pork there was a considerable saving of tankage.

The results from these experiments, as well as those with soybeans, discussed on page 305, suggest the possibility, if not the probability, of securing more profitable returns from hogging-off corn when the supplemental crop is grown independently rather than with the corn.

Kafir versus corn for hogging-off. At the Kansas Station, Anderson and Marston compared corn and kafir for hogging-off purposes in two experiments. In both trials the pigs were turned in at weights averaging about 100 pounds and remained in the fields 40 days. Both lots in each group were hand-fed tankage at the rate of ¼ pound daily. The essential results are reported separately in Table 102.

Table 102. Kafir versus Corn for Hogging Off

Rations	*Beginning Date*	*Initial Weight*	*Daily Gain*	*Feed Required for Each 1 Cwt. Gain*	
		lb.	lb.	lb.	
Corn + tankage	Sept. 13	106	1.63	Corn	[illegible]
				Tankage	[illegible]
Kafir + tankage	Sept. 13	106	1.40	Kafir	[illegible]
				Tankage	[illegible]
Corn + tankage	Oct. 13	102	[illegible]	Corn	[illegible]
				Tankage	[illegible]
Kafir + tankage	Oct. 13	102	[illegible]	Kafir	[illegible]
				Tankage	[illegible]

The pigs in corn gained faster than the pigs in kafir, and in both cases less corn than kafir was required to produce a given gain. If we assume the yield of grain to have been the same, the acre of corn is to be given credit for producing 128 pounds of pork in excess of the amount produced on an acre of kafir. If the conditions were such as to make the two experiments comparable, the results suggest that the earlier beginning date for hogging-off is preferable.

FIELD MANAGEMENT

To secure satisfactory results with the cornfield method of feeding pigs it is imperative that attention be given constantly to the essentials of good care and management. A water supply that is clean and easy of access is very important, for pigs which do not drink regularly and often do not gain well. Portable fountains are convenient when the field is away from the barn. If the field is large, several of these should be situated at different locations. A 150-pound pig will require from 8 to 10 pounds of water daily. When supplied by hand, they should be watered three times daily at least. Wooden platforms should be provided to keep the water fountain and the feeder containing the supplement out of the mud.

Pigs hogging-off corn require comfortable beds. When not working, they should be sleeping. A chilly rain in the late fall will cause the loss of a week's feeding when no adequate protection is provided against it. Whatever the type of shelter used may be, it should have a roof that will turn a heavy rain, at least two walls, usually north and west, tight enough to be wind- and rain-proof and a foundation or bottom sufficiently high to prevent the seepage or flow of water into the beds.

Well-grown shotes in feeder condition are best adapted to the cornfield method of feeding; fat pigs lack both the ambition and energy to hog-off corn successfully. Gilts which are intended for breeding should not be allowed in the field unless watched and removed before they become too fat. Yearling and older sows which are to be bred may be allowed in the field for a short time. They will help to break down the corn for the younger pigs. The sows may be used also to perform the useful service of cleaning up the field after the shotes have been removed to the dry lot for finishing. It is a mistake to keep the pigs in the field until all the corn is eaten, since to do so will result in a serious falling off in the gains, and a falling off in gains at this stage of feeding is particularly costly.

Ordinarily the pigs should not be turned into the field until the corn is well dented, since the accumulation of starch in the kernel is not completed until the grain is hard. This will be after silage cutting time and from two to four weeks before it is dry enough to crib. A standard variety of corn will give best results. What is gained in early maturity by the use of sweet corn or early varieties of field corn, in the effort to get the hogs off to market early, is generally sacrificed by the lighter yields.

Before the pigs are turned in they should be partly accustomed to new corn feeding. This preparation will help to prevent scouring and promote better gains. In case there is little down corn, it will be advisable to cut or roll down a few rows until they have learned the knack of getting it down themselves.

It will usually be necessary to do some temporary fencing when corn is hogged-off. Twenty-six-inch woven wire is the kind most suitable. The customary way of putting it up is to anchor well with solid end posts and then to tie or fasten the wire to cornstalks and an occasional driven post or stake set at suitable intervals. The top of the stalks of the fence row should be cut off to prevent damage to the fence by the pigs in their efforts to get the corn. Some recommend that the next inside row also be cut down for the same reason. The area fenced off should be no larger, as a rule, than can be hogged-off in 30 days.

Grazing capacity of an acre of corn. The carrying capacity of an acre of corn will vary, of course, with the yield, the size of the pigs, and the type of ration fed. Schedules showing the time required to hog-off an acre of corn, based on observations and experimental study, have been published by the Minnesota, Iowa, and Ohio Stations. Robison's studies include a consideration of the ration fed, as well as the yield of corn and size of the pigs, and is reproduced here, with some of the items abbreviated, in Table 103.

HOGGING-DOWN SMALL GRAIN

The practice of harvesting the small grains by turning the pigs into the field when the grain is ripe, or in the hard dough stage, is not a general one. Although it has been reported to give good results in the Pacific Northwest, where the rainfall is light, experiments throughout the Corn Belt have generally shown the practice to be an uneconomical one.

At the Missouri Station, Mumford and Weaver obtained fair results

Table 103. The Time Required by Pigs to Harvest an Acre of Corn

Rations	*Yield of Corn per Acre*	*With 10 Shotes Weighing 75–100 Lbs.*	*With 10 Shotes Weighing 100–150 Lbs.*	*With 10 Shotes Weighing 150–200 Lbs.*
	bu.	*days*	*days*	*days*
Standing corn only	35	43	29	25
	50	61	41	35
	65	79	53	46
Standing corn and soybeans (or other supplemental crop)	35	33	25	25
	50	47	36	35
	65	62	47	46
Standing corn and soybeans (or other supplemental crop) + minerals	35	29	23	..
	50	42	33	..
	65	54	43	..
Standing corn + tankage	35	34	25	19
	50	48	36	27
	65	62	47	35

when ripe rye was hogged-down. From 1908 to 1912 they pastured an average of 12 pigs to the acre for a period of 50 days. In addition to the rye the pigs received a limited hand-fed ration composed of 6 parts corn and 1 part linseed meal. It was estimated that an acre of rye in these experiments should be credited with the production of 212 pounds of pork, which was not so bad when the small yield of rye is considered.

A two-years' experiment at the Iowa Station was not favorable to the practice of hogging-down ripe rye. The first year, when 0.45 pound of meat meal was fed daily to each pig as a supplement, the daily gain averaged only 0.27 pound. The second year, when a ration of corn and meat meal was hand-fed in limited amounts, the gains were better, but the results as a whole were considered unprofitable.

Robison and Jones of the Ohio Station [6] found in two experiments that hogging-down wheat was unprofitable. The 67-pound pigs in the standing wheat gained at the rate of 0.57 pound daily during the 40-day grazing period, while those fed harvested wheat gained daily 1.25 pounds. A supplement of tankage was fed to both groups. The returns per bushel above the cost of the tankage was 73 cents for the harvested wheat, and 49 cents for the wheat which was grazed.

[6] W. L. Robison and P. A. Jones, Mimeo, Rpt., 1935.

At the Indiana Station Vestal grazed 20 99-pound shotes on 5 acres of wheat for a 50-day period, beginning June 25. When turned in, the grain was in the hard-dough state. The conditions generally were favorable to the best results; the weather was dry, young clover was coming on, and meat meal and a mineral mixture were provided in a self-feeder. The wheat was estimated to yield 32 bushels to the acre. The results, however, could not be regarded as satisfactory. With hogs worth 5 cents, the wheat had a value of 33⅓ cents a bushel; with hogs worth 6 cents, it was credited with a value of 45¾ cents; and with hogs at 8 cents, it was given a value of 70½ cents a bushel.

GRAZING CROPS FOR THE SOUTH

Although the hogging-off of corn is not practiced so generally in the South as it is in the North, it probably is true that the grazing of field crops has a larger place in southern pork production than it has in the Corn Belt. This may be due to the fact that the production of pork in the South is chiefly to meet home-consumption needs, to the extra amount of labor required when the crops are harvested by hand, and to a greater appreciation of the value of the manure left on the land over which the hogs have grazed.

The fertility benefits conferred on the soil by grazing hogs is strikingly illustrated by the results obtained at the Arkansas Station, as measured by the increased yields of cotton obtained the two years immediately following the hogging-off of peanuts, chufas, and soybeans. Following the grazing of peanuts, the increased yield of cotton amounted to 61 percent; following chufas, the increase was 21 percent; and after soybeans it was 45 percent.

Sweet potatoes. Bray and Francioni of the Louisiana Station completed a series of experiments designed to determine the place of this crop in southern pork production and the best methods of feeding them. The results of five years' work from selected experiments are briefly summarized in Table 104.

Some important facts gleaned from these studies are the following: The hogging-off of corn, sweet potatoes, and soybeans gives satisfactory results. Sweet potatoes provide feed for hogs during the late fall and early winter, following the period appropriate for hogging-off corn. An acre of potatoes that will yield 180 bushels will last 12 hogs 30 days; corn will last longer. Sweet potatoes, like corn, are highly carbonaceous and must be supplemented with protein-rich feeds. In one experiment the feeding of tankage increased the daily gains [illegible]

Table 104. Comparative Value of Sweet Potatoes in Various Combinations

How Fed	*Daily Gain*	*Feed Required to Produce 1 Cwt. Gain* *Corn*	*Sweet Potatoes*	*Protein Sup.*	*Sweet Potatoes to Equal 1 lb. Concentrates*
	lb.	lb.	lb.	lb.	lb.
Potatoes alone	0.57		4205		10.4
With protein supplement, in dry lot	1.04		1825	169	7.7
With protein supplement, hogged-off	1.41		1628	76	4.9 + vines
With corn and protein supplement, in dry lot	1.66	162	755	71	4.3
Corn and protein supplement, in dry lot	1.69	358		48	

0.87 to 1.46 lbs. The highest value from sweet potatoes is obtained when some corn and a protein supplement are fed. Four and one-half bushels of sweet potatoes are required to equal one bushel of corn. To be profitable, an acre of potatoes should yield eight times as many bushels as will corn. In 1931, 189 bushels of potatoes were produced to the acre, in comparison with 21.2 bushels of corn. It was estimated that from 2 to 4 million bushels of cull or unmarketable sweet potatoes were available for feeding in Louisiana each year. As a rule, hogs will not pay market prices for No. 1 potatoes. The experimenters quote Edwards to the effect that sweet potatoes have a hardening effect on the fat of hogs previously fed peanuts. It requires nearly twice as much labor to plant an acre of sweet potatoes as it does an acre of corn and soybeans.

Some valuable information is contained in the hogging-off experiences at the same station by Kidder and Dalrymple covering the period of 1919 to 1922 and condensed in Table 105. The results from the different crops, however, are not exactly comparable for the reason that they were grown in rotation and fed in different years.

The following specific conclusions with reference to the effect of grazing pigs on mature soybeans as regards the quality or firmness of the pork produced are made from the extensive cooperative studies conducted by the U.S. Department of Agriculture and various experiment stations of the country.

Table 105. Hogging-off Sweet Potatoes and Soybeans

Number of Tests	*Crops Hogged-off*	*Daily Gain*	*Feed for Each 100 Pounds Gain*		*Yield per Acre*		*Pork Produced from 1 Acre*
		lb.	lb.		bu.		lb.
4	Corn + cowpeas [a]	0.98	Corn Cowpeas	555 39			273
2	Corn + soybeans [b]	1.01	Corn Soybeans	316 100	Corn Soybeans	12.4 4.4	255
2	Corn + soybeans + sweet potatoes	1.71	Corn Soybeans Potatoes	193 20 378	Corn Soybeans Sweet potatoes	15.4 2.0 97.5	289
3	Soybeans + sweet potatoes	1.42	Corn Soybeans Potatoes	14 97 870	Soybeans Sweet potatoes	10.7 102.0	288
1	Sweet potatoes [c]	1.02	Potatoes Shrimp meal	1976 45	Sweet potatoes	75.0	212

[a] Cowpeas were mostly forage.
[b] Soybeans and corn planted separately but hogged-off together.
[c] Ate 7.5 pounds of shrimp bran in addition per hog.

1. Soybeans grazed alone or with minerals self-fed to pigs starting at weights ranging from 85 to 160 pounds and making at least a moderate rate of gain through a period of from 6 to 8 weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn and tankage double that previously made on soybeans.

2. Soybeans grazed with a supplementary ration of 2.5 percent of shelled corn (2½ pounds daily per hundredweight of pig) with or without minerals self-fed to pigs starting at weights ranging from 85 to 114 pounds and making gains approximately 20 to 60 pounds through a period of from 6 to 8 weeks will not produce firm carcasses in the usual case even though a subsequent gain in weight has been made by the pigs on corn and tankage equal to that previously made on the soybeans—2.5 percent corn ration.

3. Soybeans grazed with a supplementary ration of 2.5 percent of shelled corn with or without minerals self-fed to pigs starting at weights of 115 pounds and over and making gains of approximately 40 to 90 pounds through a period of from 6 to 8 weeks will produce firm carcasses in the usual case provided a subsequent gain in weight is made on corn with tankage 1.5 times that previously made on the soybean—2.5 percent corn ration.

4. Soybeans grazed with a supplementary ration of 1.5 to 2.5 percent of shelled corn and with minerals self-fed to pigs starting at weights ranging from 25 to 85 pounds and making gains of approximately 40 to 75 pounds through a period of from 8 to 10 weeks produce, in the usual case, carcasses of satisfactory degree of firmness when a subsequent gain in weight of 125 pounds or more has been made by the pigs on corn and tankage.

More recent studies by Halverson and associates at the North Carolina Station,[7] over the period from 1937 to 1942, emphasize the importance of supplementing soybeans that are being hogged down with both protein and minerals, and of feeding a hardening diet after the pigs reach a weight of 85 pounds in order to avoid a high percentage of soft carcasses.

Peanuts. This is considered one of the valuable legume crops of the South especially adapted to light sandy soils. The underground seeds or nuts are rich in oil and protein, are particularly relished by hogs, and when foraged along with the proper supplements give good results. The North Carolina or Georgia variety of peanut when planted early in the spring will be ready for grazing by the middle of September. Due to the fact that the matured seeds do not sprout in the ground, as does the Spanish variety, it may be grazed during the winter up to March 1. The Spanish variety is a quicker grower and is ready to hog off 6 weeks earlier than the former kind, but does not yield nearly as heavily.

At the Texas Station, Warren[8] grazed 10 March-farrowed pigs on peanuts alone from September 24 to November 20, a period of 57 days. Another similar group was grazed on peanuts for 30 days, following which for 27 days milo chop and cottonseed meal were hand-fed in the ratio of 6 to 1, in the dry lot. Three other similar groups were fed rations in the dry lot as shown in Table 106.

The pigs which grazed the peanuts with no other feeds made exceptionally good gains. The fields were estimated to yield 25 to 30 bushels of nuts to the acre. The five acres of peanuts grazed produced 1396 pounds of pork. The principal object of the experiment, however, was to determine the effect of peanut feeding on the quality of pork. All the pigs which grazed peanuts for the entire period with no other feeds killed "soft" and were docked by the packers $2 a hundred, live weight. Of the pigs which grazed the peanuts 30 days only, followed by 27 days on hardening feeds in the dry lot, only three killed "soft"; the other seven killed firm and were not docked. The practice illustrated in this lot was deemed a profitable one. Practically all the pigs in the other lots killed hard.

Peanuts tend to produce "soft" hogs, but the fault is said not to be considered serious by those who are acquainted with the superior flavor of peanut-fed pork. Packers, however, discriminate against such hogs. If fed with corn or grazed with sweet potatoes, velvet beans,

[7] J. O. Halverson, E. H. Hostetler, and F. H. Smith, *Jr. An. Sci.*, Vol. 6, No. 4, 1947.
[8] G. R. Warren, Bul. 305, 1923.

Table 106. Grazing Peanuts Compared with Other Feeding Methods

Rations	Initial Weight	Daily Gain	Daily Feed Consumption	Feed Eaten Each 1 Cwt. Gain	
	lb.	lb.	lb.	lb.	
Grazed peanuts, 57 days	119	1.61		Grazed peanuts	
Corn chop + tankage, self-fed, free-choice, 57 days	119	2.06	9.31	Corn	426
				Tankage	25
				Total	451
Milo chop + cottonseed meal, self-fed, free-choice, 57 days	119	1.52	7.04	Milo	458
				Cotton m.	5
				Total	463
Milo chop + peanut meal, self-fed, free-choice, 57 days	119	1.50	7.04	Milo	464
				Peanuts	7
				Total	471
Grazed peanuts, 30 days; milo chop 6 + cottonseed 1 meal, hand-fed, 27 days	118	1.55	6.29 [a]	Milo	357
				Cotton m.	60
				Total	417

[a] Based on feed consumed and gains made during the 27-day dry-lot period only.

or chufas, or if followed by a dry-lot finishing period with hardening feeds, the difficulty will be somewhat alleviated. In these experiments the Spanish variety of peanuts was used. The results were considered very satisfactory especially when consideration was given to the poor type of soil producing them and the fertility benefits conferred on the soil for following crops.

At the North Florida Station, Kirk and associates [9] conducted winter and summer grazing trials in which corn, peanuts, cowpeas, and sweet potatoes were compared. The soil was a fine sandy loam better adapted to corn than to peanuts. A summary of the three summer grazing experiments are given in Table 107.

In these trials it was found that corn and Spanish peanuts planted early in the spring would be sufficiently mature from July 1 to 15 to permit grazing, while Florida runner peanuts and sweet potatoes could be grazed beginning in October. It would appear from the results above that corn, with tankage supplement, was the most profitable crop for summer grazing.

In three winter grazing experiments the same authors compared Florida runner peanuts, alone and in various combinations, with sweet potatoes for growing and fattening pigs with results as summarized in Table 108.

[9] W. G. Kirk, L. O. Gratz, and V. E. Whitehurst, Jr., Bul. 339, 1943

Table 107. Summer Grazing Trials at the North Florida Station
(Average 3 Experiments, 1937–1941)

Grazing Crops	*Corn Alone*	*Corn and Tankage*	*Corn and Cowpeas, Interplanted*	*Corn and Spanish Peanuts, Alternate Rows*	*Spanish Peanuts Alone*
Total number of pigs	23	23	24	15	12
	lb.	lb.	lb.	lb.	lb.
Average initial weight	91.5	92.7	92.0	90.3	93.1
Average final weight	198.7	228.3	201.9	215.3	205.4
Average daily gain	1.27	1.75	1.35	1.44	1.60
Average gain per acre of crop	421	533	451	321	230
Feed to produce 1 Cwt. gain:					
Corn	691	536	693	556	....
Cowpeas	....	....	no estimate	....	....
Spanish peanuts	....	....	....	75	483
Tankage	....	23.2	....	....	....
Minerals	4.43	0.61	3.43	3.28	3.27

Table 108. Winter Grazing Experiments at the North Florida Station
(Average 3 Experiments)

Grazing Crops and Supplements	*Florida Runner Peanuts Alone*	*Florida Runner Peanuts and Tankage*	*Florida Runner Peanuts, Green Oats, and Tankage*	*Sweet Potatoes and Tankage* [a]
Total number of pigs	14	15	15	48
	lb.	lb.	lb.	lb.
Average initial weight	80.6	79.7	79.5	87.6
Average final weight	182.9	185.7	188.0	173.9
Average daily gain	1.49	1.69	1.74	1.11
Average gain per acre crop	245	272	278	531
Feed to product 1 Cwt. gain:				
F. Runner peanuts	542	430	445	....
Green oats	....	....	ad lib.	....
Tankage	....	21.5	14.8	67.8
Sweet potatoes	....	....	....	3998
Minerals	3.62	1.36	1.23	0.43

[a] Average four trials.

Although the pigs which grazed the sweet potatoes made the slowest daily gains, the amount of pork produced per acre was practically

double that which was secured from an acre of the peanuts. The results emphasize, also, the importance of feeding a protein supplement under such circumstances.

Chufas. Planted from April to June, chufas will produce 75 to 150 bushels of tubers per acre which may be hogged off any time during the winter. They are cheaply grown, do best on light sandy soils, and are eaten with great relish by pigs. Because of their carbonaceous character they should be supplemented by the addition of protein-rich feeds, such as tankage, fish meal, shrimp meal, milk by-products, or soybean oil meal with a good mineral mixture. Like peanuts, chufas produce soft pork.

Velvet beans. This legume is adapted to the light soils along the Gulf. In the northern half of the Gulf states, however, it does not produce as well as soybeans or cowpeas. The velvet bean produces a trailing vine and should be planted with a supporting crop, such as corn, which will give good results when hogged off. The method of planting which is believed to yield the largest return in pork when grazed is in conjunction with corn and peanuts, the corn and peanuts in alternate rows and the velvet beans planted later in the same row with either the corn or peanuts. Frequently it is planted in corn, one row of beans alternating with two rows of corn. Grown with corn, it has yielded as high as 40 to 60 bushels to the acre. The beans are rich in protein and with corn make a well-balanced ration. The addition of minerals probably would prove beneficial.

Other root crops. Artichokes and mangels are sometimes used as grazing crops for hogs. The large amount of hand labor involved in growing them, however, and their bulky watery character preclude their general use in pork production. Artichokes grown on rich loose soil containing an abundance of humus will give fair returns. At the Oregon Station, French grazed six 162-pound pigs on one-eighth of an acre from October 22 to December 11, securing an average daily gain of 0.81 pound. The pigs were fed in addition a light grain ration. It was estimated that the root saved 2 pounds of grain in the production of each pound of pork. Evvard and associates of the Iowa Station secured a yield of 226 bushels of artichokes to the acre. When hogged-up with a limited ration of corn and tankage, they gave fairly satisfactory results. The authors were doubtful, however, if the crop would pay unless profitable use were made of the tops. Jerusalem artichokes are recommended as a crop for swine by Krauss of the Hawaii Station. Mangels are grown successfully on the rich alluvial bottom lands of the South and may profitably be used as a winter grazing crop.

XII Protein Supplements —Dairy By-products

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Attention has already been given to the fact that corn and the other cereal grains are particularly deficient in proteins, minerals, and vitamins (see Chapters VII and VIII). Since the grains constitute the bulk of the feedstuffs used in pork production everywhere, it is apparent at once that extensive use must be made of supplemental feeds if good nutrition is to be maintained and economical production made possible. Forage and grazing crops possess these supplementing qualities, as we have just seen in the preceding chapters; but due to their bulk and the fact that they are available only for part of the year, they can be depended on for a part of the needs only. Recourse to commercial feeds is therefore necessary if the home-grown grains are to be fed in a manner that will ensure their most effective use, particularly during the winter season.

The supply of protein supplements. The extent to which the various commercial protein feeds are made use of is limited of course by their supply. In Fig. 51 the annual tonnage production available for feeding in the United States is shown diagrammatically for those manufactured feeds most extensively used in pork production. Of the feeds listed, cottonseed meal, wheat bran, and skim milk are used less exclusively in pig feeding than is true of any of the others. Since only a small proportion of the production is involved in foreign trade, the figures represent fairly accurately the supply available to the American feeder. Not all of these feeds reach the feeder in their original form, however, for the reason that a proportion of each is used in the manufacture of commercial mixed feeds.

The present supply of these feedstuffs represents in practically all cases an increased production, compared with that for the period 1927 to 1934, about equal to the increase which has occurred in general agricultural production. This has been moderate and gradual

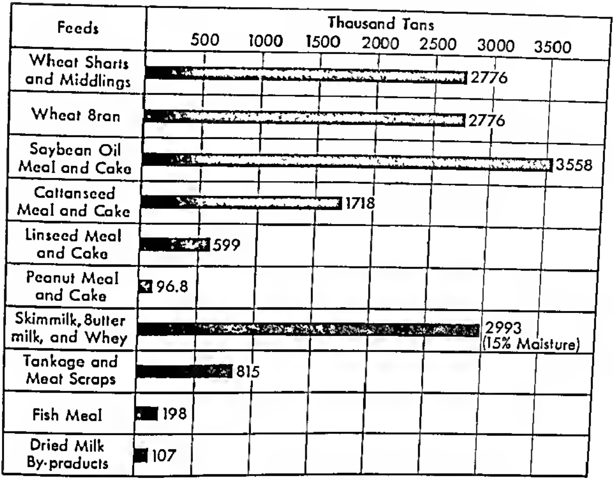

Fig. 51. Average annual tonnage supply of protein concentrates in the United States, 1943 to 1947, inclusive *(U.S.D.A., Agr. Statistics, 1948; Earle O. Whittier, "Am. Butter and Cheese Review," Vol.* 12, *No.* 1, January, 1950*)*.

except in the case of soybean oil meal. The supply of this protein-rich swine supplement now exceeds that of any other feed, its production having increased more than 40 times during the past 20 years.

Our production of oil meals generally exceeds our consumption. In 1948 the net exports (exports minus imports) of cottonseed meal amounted to 82,200 tons; of soybean oil meal, 146,900 tons; of linseed meal, 45,900 tons; and of peanut oil meal, 20,200 tons. In the case of wheat mill feeds, on the other hand, the net imports were 121,500 tons; of fish meal, 45,800 tons; and of tankage, 37,800 tons.[1]

The relative importance in terms of value of the various by-product feeds in the United States is shown in Table 109, which represents calculations by Paarlberg of the Indiana Station [2] of the U.S. Department of Agriculture data.

[1] *Feed Statistics, Statistical Bul. 85, Bureau Agr. Ec.*, U.S.D.A., Dec., 1949.
[2] Don Paarlberg, Bul. 538, 1949.

Table 109. Relative Importance of Various By-product Feeds in the United States, 1948 and Pre-War

	Percent of total value year beginning October:	
	Average, 1937–41, Percent	*Average, 1948 Percent* [a]
Oilseed meal and cake:		
Soybean meal and cake	10	21
Cottonseed meal and cake	15	13
Linseed meal and cake	4	3
Peanut meal and cake	1	1
Copra meal and cake	1	1
Animal proteins:		
Tankage and meat scrap	9	7
Fish meal	3	2
Commercial dried-milk products	3	2
Grain protein feeds:		
Gluten feeds and meal	4	4
Brewers' dried grains	1	1
Distillers' dried grains	2	2
Other by-product feeds:		
Wheat millfeeds	29	26
Rice millfeeds	1	1
Dried molasses beet pulp	2	1
Alfalfa meal	3	5
Miscellaneous by-product feeds [b]	12	10
Total	100	100

[a] Preliminary.
[b] Includes hominy, oat millfeeds, molasses and screenings. Does not include noncommercial milk products.

The prices of protein supplements. Variations which have occurred in the average annual prices of these feeds during the period 1938 to 1947 inclusive are shown in Fig. 52. The changes from year to year during this time are in the main a reflection of the general economic conditions resulting from the war. Like all other commodities, feed prices were relatively high and constant during the war years. Price inflation during the postwar period was responsible for the extreme prices reached in 1947. Feed prices may be expected to fall only when the general price level declines.

Compared with feed prices during the prewar period (1935 to 1939), the average price of the 10 major protein supplements had increased 240 percent by 1949. The price of tankage, meat scraps,

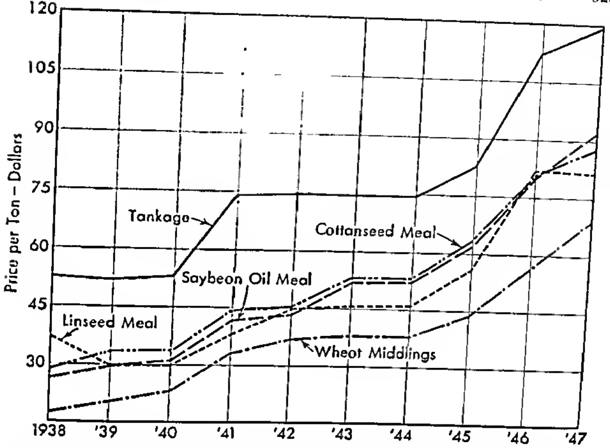

Fig. 52. Average annual price per ton, bagged, protein supplements, 1938 to 1947, inclusive—tankage and soybean oil meal at Chicago, linseed meal and middlings at Minneapolis, cottonseed meal at Ft. Worth *(U.S.D.A., Agr. Statistics, 1948)*.

and fish meal increased by 328 percent, and the four oil meals by an average of 219 percent.[3]

During these years prices for the different feeds paralleled one another rather closely. It is of interest to the feeder also to observe the rather constant relationship between the prices of the different feeds. On the average, during this 10-year period, taking the price of 60 percent tankage at 100 dollars a ton, the other feeds at their respective points were selling, in round numbers, as follows: 43 percent cottonseed meal, 68 dollars; 41 percent soybean oil meal and 32 percent linseed meal, each 66 dollars; middlings, 37 dollars; and bran, 36 dollars. Sixty-seven percent fish meal, not shown in the graph, sold in San Francisco during this period 10 dollars a ton higher than tankage in Chicago.

Prices of the cereal grains are shown in Figure 56.

The average prices by months of these protein supplements for the period of 1940 to 1948 are shown diagrammatically in Fig. 53. Al-

[3] *Feed Statistics, Statistical Bul. No. 85, Bur. Agr. Ec.,* U.S.D.A., 1949.

though none varied widely from month to month, there were differences which suggest that different types of feeds follow certain patterns. The by-products from the oil-producing seeds, cottonseed meal, linseed meal, and soybean oil meal, for example, sold highest in July

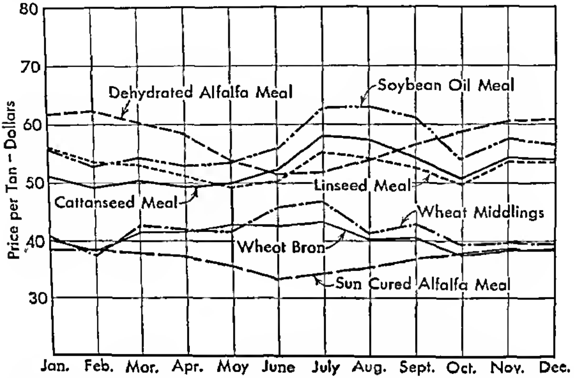

Fig. 53. Average monthly wholesale prices of common protein supplements, 1940 to 1948. Prices are per ton bagged—bran, middlings, and linseed meal at Minneapolis; cottonseed meal at Memphis; soybean oil meal at Chicago; alfalfa meal at Kansas City *(U.S.D.A., Market News and Service Division).*

and August and lowest in April and May. Prices for bran and middlings also were highest in July and lowest during the early winter, although a study of the price changes in the individual years supplied little evidence that season is an important factor with these two feeds. In the case of alfalfa meal a regular decline in price occurred from January to June, and a gradual increase in price from July to January.

DAIRY BY-PRODUCTS

The by-products resulting from the use of milk in the manufacture of butter, cheese, condensed and dried milk, etc., constitute one of the large sources of protein available to the farmer for balancing home-grown grains. These are chiefly skim milk, buttermilk, whey, and condensed or semisolid buttermilk. Of the 26 million tons of skim milk received or produced by processors in 1947, less than 30 percent was

consumed as human food; about 40 percent of the buttermilk was condensed or dried, most of which was fed to livestock; and about 23 percent of the whey was dried and used mainly in chicken feeds.[1]

Skim milk, buttermilk, semisolid and dried buttermilk, on the dry-matter basis, are practically the same in composition as the mother milk with the fat removed. The butterfat contains much of the energy and fat-producing qualities of the whole milk as well as practically all of the fat-soluble vitamins, but there are left after its removal all the proteins and minerals, and these are the nutrients of which Corn Belt rations stand in greatest need. Milk proteins are superior to the proteins of most other supplements, especially those of plant origin, because they contain a good supply of the particular proteins or amino acids, which are insufficiently contained in the grains. The minerals of milk are fairly high in calcium, phosphorus, and common salt, but deficient in iron and copper.

Food deficiencies of milk by-products. None of the dairy by-products are complete feeds, however. In common with practically all the commercial supplements, skim milk, buttermilk, whey, semisolid buttermilk, and dried milk are devoid practically of any vitamin A or D. However, milk is one of the richest feed sources of riboflavin (vitamin B_2). Although water-soluble, much more is found in buttermilk than in skim milk. The other water-soluble vitamins are contained only in fair amounts. Adding to a corn-milk ration high grade sun-cured alfalfa meal in an amount to represent 10 to 12 percent of the dry feed by weight, or providing fresh green forage, will ensure protection against any known vitamin deficiency.

Whole milk not a perfect food. According to Hart and associates

tional gains. They attained the weight of 200 pounds in 4½ months, which represented a rate of gain from birth of 1.48 pounds daily. Perhaps the most spectacular feature of the performance was that only 1.97 pounds of dry matter were required for each pound of gain; for the pigs fed the standard ration, 3.53 pounds were necessary for 1 pound of gain. The results of this study are most suggestive and give further insight into the feeding qualities of the milk by-products.

Whole milk also is deficient in iron, for as we have seen in Chapter IV, when nursing pigs are limited to the mother's milk alone, anemia results.

Table 110. Composition of Milk and Milk Products[a]

	Dry Matter	*Protein*	*N-free Extract*	*Fat*	*Calcium*	*Phosphorus*	*Total Minerals*
	%	%	%	%	%	%	%
Whole milk	12.8	3.5	4.9	3.7	0.12	0.09	0.70
Skim milk	9.5	3.6	5.1	0.1	0.13	0.10	0.70
Buttermilk	9.4	3.5	4.5	0.6	0.14	0.08	0.80
Condensed or semi-solid buttermilk	29.7	10.9	12.6	2.2	0.44	0.26	4.00
Dried buttermilk	92.4	32.4	43.3	6.4	1.36	0.82	10.00
Whey	6.9	0.9	5.0	0.3	0.05	0.04	0.70

[a] F. B. Morrison, *Feeds and Feeding*, 21st Ed., Morrison Publishing Co., Ithaca, N. Y. Table I, Appendix, 1948; H. H. Mitchell and F. J. McClure, Bul. 99, Nat. Res. Council, 1937.

SKIM MILK AND BUTTERMILK

Skim milk and buttermilk of equal value. Reference to Table 110 will show these two milk products to be practically identical in composition as expressed by the usual chemical analysis. Furthermore, all feeding experiments in which the two have been compared as supplements to corn have failed so far to show any differences in food properties not revealed by chemical analysis. Of course, this refers to buttermilk undiluted with the churn washings and before either has suffered deterioration from long standing and putrefaction. Yet these two products are very unlike in taste and bacterial content; when fresh, one is sour and the other sweet. The lactic-acid—producing bacteria, which abound in buttermilk, are believed to benefit digestion through the influence which they exert in controlling the character of the bac-

terial growth of the intestinal tract. So far as we know at this time, however, we may safely apply the results of feeding tests from one to the other.

Proportions of skim milk or buttermilk to feed with corn. The amount of skim milk or buttermilk required to supply the protein deficiencies of corn for growing and fattening pigs of different ages is indicated in Table 111. The minerals supplied by these proportions, also, although not abundant, will be adequate for normal growth.

Table 111. The Proportion of Skim Milk or Buttermilk Required to Balance Corn

For 50-lb. Pig	*For 100-lb. Pig*	*For 150-lb. Pig*	*For 200-lb. Pig*	*For 250-lb. Pig*
1 corn to 4 milk	1 corn to 3 milk	1 corn to 2 milk	1 corn to 1½ milk	1 corn to 1¼ milk

In practice it frequently will be profitable to feed a larger proportion of milk than is indicated in the table, especially for pigs weighing 150 pounds and more. When there is a surplus of milk, and corn is scarce and relatively high in price, larger amounts will pay, even though the unit value of the milk will thereby be reduced. When given all the milk they will take in three feedings a day, pigs will consume from seven to nine times as much milk as corn self-fed. Usually, the younger the pig, the larger will be his consumption of milk compared with corn. Although this heavy consumption necessitates the digestive accommodation of a large volume and of handling an amount of water which is in excess of the normal body requirements, the pig's capacity to make gains does not seem to be affected.

In Robison's experiments at Ohio,[7] increasing the ratio of milk to corn from one part of corn to one of milk to three, five, seven and nine parts of milk produced the gains 1.058, 1.176, 1.299, and 1.573 daily, respectively. These figures represent the averages from two experiments. The individual experiments gave results which paralleled the averages. In a similar test, Ferrin and Johnson of Minnesota[8] fed four groups of pigs corn and buttermilk in different proportions. One part of corn was fed with two, three, five, and seven parts of milk, respectively, in the different lots. The gains, which represent the averages from two experiments, were 1.480, 1.375, and 1.355 pounds

[7] W. L. Robison, Bul. 349, 1921.
[8] E. F. Ferrin and D. W. Johnson, H-56, 1932 and H-59, 1933.

daily. These results were consistently shown in the individual experiments.

When a limited supply of milk is available and corn is relatively cheap, on the other hand, it will not be profitable to feed more than necessary to balance the grains. In this situation especially it often will be advisable to make use of a second supplement along with the milk. Excellent results are always secured in rate and economy of gains when any of the standard protein feeds like tankage, middlings, or linseed or soybean oil meal is used as a partial supplement with milk. In fact, a combination of the two seems to be more efficient than either alone, as shown in Table 114. As a rule, the smaller the amount of milk fed, the greater is its unit value. The unit value, however, does not furnish a reliable basis for determining the proportion which would be most profitable to feed under a given set of conditions.

The money value of skim milk. Probably the best basis to use for figuring the value of skim milk is using the results obtained from experiments in which it is compared with a standard supplement like high-grade tankage. Obviously the price one can afford to pay should not be based on the saving of feed effected when fed against corn alone. It would be more logical to do this if no other supplements were available. With many such supplements on the market, however, its value is most accurately measured by comparing the feeding results with those with which it must compete.

In Table 112 are given the results of 10 feeding trials conducted at the Ohio and South Dakota Stations, in each of which corn and skim milk or buttermilk were fed to one group of pigs in the dry lot and corn and high-grade tankage to another similar group under the same conditions. The summary includes the data from those experiments only in which full rations were fed in both lots and the time covered extended over most of the growing and fattening period. The pigs were mostly fall-farrowed and weighed from 43 to 82 pounds at the beginning for the different experiments, the average being 60. The proportion of milk fed averaged practically 2 pounds for each pound of corn, while the tankage amounted to 10 percent of the ration. As a result, the proportion of protein supplied in the two contrasting rations was practically identical.

As usually is the case, the pigs which received skim milk outgained those fed tankage. In 3 of the 10 trials, however, the tankage-fed pigs made the faster gains. The rate as well as the economy of gains would indicate that nutrition was good in both lots and that no serious food

Table 112. Skim Milk or Buttermilk Compared with Tankage
(Average 10 Experiments)

Rations	*Beginning Weight*	*Daily Gain*	*Feed to Produce 1 Cwt. Gain*		*Daily Ration*	
	lb.	lb.	lb.		lb.	
Corn + skim milk			Corn	288	Corn	3.79
or buttermilk	60	1.314	Skim milk	567	Skim milk	7.45
			Corn	361	Corn	4.26
Corn + tankage	60	1.180	Tankage	37	Tankage	0.44

deficiency existed in either ration. However, if yellow instead of white corn had not been fed and access to the open and sunshine not been given, some nutritional disturbances would have occurred in both lots (see page 221).

In producing 100 pounds of gain, 567 pounds of milk replaced or had the value of 73 pounds of corn and 37 pounds of tankage. Using these values it is possible to determine what skim milk is worth with varying prices for corn and tankage. The results of such a computation are shown in Table 113 for a rather wide range of feed prices.

Table 113. Showing the Value of 100 Pounds of Skim Milk or Buttermilk as Related to the Price of Corn and Tankage

Corn per Bushel	*Tankage per Ton* $40	$50	$60	$70	$80	$90	$100	$125	$150
50¢	24¢	28¢	31¢	34¢	38¢	41¢			
60¢	26¢	30¢	33¢	37¢	40¢	43¢	46¢		
70¢	28¢	32¢	36¢	39¢	42¢	46¢	49¢	57¢	
80¢	30¢	34¢	38¢	41¢	45¢	48¢	51¢	59¢	
90¢		37¢	40¢	43¢	47¢	50¢	53¢	61¢	69¢
$1.00			43¢	46¢	49¢	52¢	56¢	64¢	71¢
$1.25			48¢	51¢	54¢	57¢	60¢	69¢	77¢
$1.50				55¢	59¢	62¢	65¢	74¢	82¢
$1.75					66¢	69¢	73¢	81¢	89¢

Assuming a constant ratio between the price of corn and tankage, it is possible to state the value of skim milk or buttermilk in terms either of corn or tankage. For the 10-year period, 1939 to 1948, the estimated price paid by farmers for 60 percent tankage represented, on the weight basis, approximately 2.2 times the price he received for his corn.[9] The feed replaced or saved by 100 pounds of milk in these

[9] *Statistical Bul.* No. 85, U.S.D.A., Bur. Agr. Ec., Dec. 1949.

experiments was equivalent therefore to 27.3 pounds of corn or of 12.4 pounds of tankage. These calculations give results which support the following general rules:

One hundred pounds of skim milk or buttermilk are worth approximately one-half a bushel of corn.

One hundred pounds of skim milk or buttermilk are worth approximately 62 percent of the value of a ton of tankage divided by 100.

Improving a ration of corn and buttermilk. Although skim milk and buttermilk are probably the most efficient single supplements known for balancing corn for pigs in the dry lot, it has been shown that they can be improved upon. Kuhlman and Wilson of the South Dakota Station [10] showed quite clearly in two experiments that when part of the buttermilk in a corn-buttermilk ration is replaced with tankage, the gains are both more rapid and economical. The results of these tests, one of which was run during the fall and the other in winter, are averaged and shown in Table 114. The pigs in each lot were fed from a beginning weight of 57 pounds to a finishing weight of 226 pounds. The corn fed was yellow. Full rations were fed excepting that the amount of buttermilk was limited to the quantity which would balance the respective rations most efficiently.

Table 114. Adding Tankage to a Corn-Buttermilk Ration
(Average 2 Experiments)

Rations	*Initial Weight*	*Daily Ration*		*Daily Gains*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.		lb.	lb.	
Corn + buttermilk	57	Corn	4.54	1.53	Corn	297
		Buttermilk	9.35		Buttermilk	611
Corn + buttermilk +		Corn	5.39		Corn	317
tankage	57	Buttermilk	4.83	1.70	Buttermilk	284
		Tankage	0.34		Tankage	19.95

The pigs which received both buttermilk and tankage gained 12 percent faster and were ready for market 11 days earlier than the pigs fed buttermilk only. This difference was the result apparently of the greater palatability of the ration containing both the supplements, for the daily consumption of this ration was 12 percent greater than the other. Part of the difference, however, may have been due to the fact that the ration containing the tankage provided a more adequate supply of calcium and phosphorus as well as about 15 percent more

[10] Arthur H. Kuhlman and James W. Wilson, Bul. 216, 1925.

protein. Only in the case of the calcium, however, was the quantity supplied in the buttermilk ration below the amount generally regarded as most desirable.

From the standpoint of the practical feeder, the use of both supplements paid. With corn at one dollar a bushel and buttermilk at 50 cents a hundred, the tankage fed in these experiments returned a value of $128 a ton. Especially when the supply of milk is limited, tankage and similar supplements will be found most valuable. When use is made of two sources of protein, as in these experiments, it is important that the amount fed be strictly limited so that the protein supply shall not exceed what is necessary to balance the ration.

Headley of the Nevada Station [11] found in one dry-lot experiment that feeding 4 pounds of skim milk daily to each pig, as an addition to a ration of ground wheat, self-fed, a protein supplement composed of 40 percent meat scraps and 30 percent each of linseed meal and alfalfa meal, self-fed, resulted in increasing the gains from 1.29 to 1.44 pounds daily.

Replacing skim milk with a plant supplement. Three experiments by Bohstedt and associates at the Wisconsin Station [12] make possible a study of the effect of replacing part of the skim milk with a plant supplement composed of equal parts linseed meal and standard wheat middlings. In these experiments, which were with pigs fed full rations in the dry lot from a weight of 52 to 200 pounds, the basal ration contained, in addition to the skim milk, 5 percent of chopped alfalfa hay and 2½ percent of a mineral mixture made up of one part ground limestone, one part of steamed bone meal, and one-half part iodized salt. The quantity of skim milk fed amounted on the average to 8 pounds daily for each pig, which was in the ratio of two parts of milk to one of corn. This ration is compared here with one in which half the skim milk was replaced with the linseed meal and middlings supplement. The latter was fed in an amount which made the protein supply practically the same in the two rations. The mineral needs of the pigs of both lots were abundantly provided for by the 2½ percent mineral mixture fed. The purpose of the alfalfa was to ensure against any possible deficiency in the supply of vitamins. The results from these three experiments are averaged and shown in Table 115.

The ration which contained the linseed meal and middlings in place of half the skim milk proved more palatable and the pigs gained [illegible]

[11] F. B. Headley, Bul. 175, 1945.
[12] G. Bohstedt, J. M. Fargo, and W. M. Beeson, [illegible]

Table 115. Skim Milk versus Skim Milk and Plant Supplement
(Average 3 Experiments)

Rations	*Initial Weight*	*Daily Ration*		*Daily Gains*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.		lb.	lb.	
Corn + skim milk	52	Corn	3.79	1.18	Corn	321
		Skim milk	7.49		Skim milk	635
		Alfalfa	0.20		Alfalfa	17
		Minerals	0.10		Minerals	8.7
Corn + skim milk + plant supplement	52	Corn	3.71	1.26	Corn	294
		Skim milk	4.01		Skim milk	318
		Plant sup.	0.84		Plant sup.	66
		Alfalfa	0.24		Alfalfa	19
		Minerals	0.12		Minerals	9.8

what faster. On the dry-matter basis, the pigs in this lot consumed nearly 20 percent more feed daily than those getting skim milk as the only protein supplement. This was responsible for the difference in the rate of gain, although the gains did not differ as widely as the difference in food consumption would suggest. The amount of corn and skim milk saved by the plant supplements fed was such as to give these feeds fair values.

Adding alfalfa hay to a corn-milk ration. Results secured by Morrison and associates of the Wisconsin Station,[13] in three experiments in which pigs were full fed in the dry lot from a weight of 50 to 200 pounds, suggest that the addition of chopped alfalfa hay to a ration of yellow corn and skim milk is advantageous. The average daily feed consumption and gains made in these trials are shown in Table 116.

Table 116. Chopped Alfalfa Hay Added to a Yellow Corn-Skim-Milk Ration

Rations	*Initial Weight*	*Daily Ration*		*Daily Gains*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.		lb.	lb.	
Yellow corn + skim milk	50	Corn	3.67	1.03	Corn	356
		Skim milk	6.92		Skim milk	672
Yellow corn + skim milk + chopped alfalfa hay	50	Corn	3.95	1.11	Corn	356
		Skim milk	7.37		Skim milk	664
		Alfalfa hay	0.21		Alfalfa hay	19

The addition of this small amount of alfalfa seemed to have an appetizing effect, for the pigs on this ration ate nearly 7 percent more feed and gained at a rate of a little more than 7 percent faster than

[13] F. B. Morrison, J. M. Fargo, and G. Bohstedt, *Proc., Am. Soc. An. Prod.*, 1929.

those on the straight corn-skim-milk ration. Although 19 pounds of alfalfa had the value of only 8 pounds of milk in these experiments, the feeding of fine-quality legume hay is strongly to be recommended in this situation, especially during the winter in the northern latitudes. When fed at the level of 5 to 10 percent of the dry ration, it will ensure more adequate supplies of vitamins A, D, and those belonging to the B-complex group.

Skim milk and tankage compared for weanling pigs. The milk by-products are especially adapted to young pigs. At the Minnesota Station, Ferrin and associates [14] compared skim milk and tankage for 42-pound weanling pigs fed until they had doubled their weight. One group of 10 pigs was fed the ration of shelled corn, self-fed, and flour middlings and skim milk mixed and fed as a slop; the other comparable group was given shelled corn, self-fed, and flour middlings and tankage, mixed and fed with water as a slop.

Table 117. Skim Milk versus Tankage for Weanling Pigs

Rations	*Initial Weight*	*Final Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	lb.	
Corn + flour middlings + skim milk	42	84	0.936	Corn	202
				Flour mids.	53
				Skim milk	432
Corn + flour middlings + tankage	42	84	0.718	Corn	307
				Flour mids.	56
				Tankage	49

According to the results as shown in Table 177, the pigs getting the milk made the faster gains, although both lots did exceptionally well. A third group was fed the same tankage ration as given Lot 2, and rape forage in addition. These pigs gained faster than those receiving the same ration without the forage, but not as fast as those getting milk.

the production of gains with growing and fattening pigs has been studied by Day of Ontario and Henry of the Wisconsin Station.[18] Day fed from 2½ to 6 pounds of whey with each pound of a meal mixture composed of small grains and wheat shorts. The average of seven trials gave an average of 744 pounds of whey as equivalent to 100 pounds of meal. Henry fed from 2 to 10 parts of whey with each pound of a combination of equal parts of corn and shorts. The average of 10 trials showed 758 pounds of whey to have the value of 100 pounds of meal.

Studies by Morrison and associates of the Wisconsin Station[19] suggest that the protein of whey is of superior quality. They fed one group of well-grown shotes weighing from 125 to 150 pounds at the start barley, self-fed, and whey; on the average, 2.3 pounds of whey were consumed for each pound of barley. A comparable group of pigs was fed barley and tankage in a self-feeder. The results of two trials gave 558 pounds of whey the value of 100 pounds of barley in producing gains. Those getting whey gained 2.22 pounds daily and the tankage-fed pigs 1.64 pounds. Further studies by the same investigators indicated that for younger pigs the protein supplied in a ration made up of grain and whey should be increased by feeding with the whey some concentrated protein supplement.

The best results in feeding whey can be obtained only when it is fed in mixed rations and along with other protein supplements. Under these conditions we may regard it as worth about one-half as much as skim milk or buttermilk.

Cheese meal is superior to tankage. This meal represents the finely ground or powdered parings which are scraped off cheese preparatory to the manufacture of processed cheese. A considerable tonnage of the by-product is produced annually. It is a protein-rich feed, very similar in composition to tankage, containing 60 percent of protein and 7 percent of fat.

Based on the results of three feeding trials with growing and fattening pigs, Bohstedt and Fargo of the Wisconsin Station[20] report that when the cheese meal was substituted for tankage, pound for pound, in the standard ration containing in addition ground corn, linseed meal, ground alfalfa hay, and iodized salt, it resulted in somewhat more efficient gains. When the cheese meal replaced one-half the tankage there was an improvement in the rate and economy of gains

[18] W. A. Henry, An. Rpt., 1891.
[19] F. B. Morrison, Bul. 319 and 323, 1920.
[20] G. Bohstedt and J. M. Fargo, Bul. 435, 1936.

experience of feeders in showing that sweet and sour skim milk are of equal value when fed with corn to growing and fattening pigs. In these experiments pigs on bluegrass pasture were fed from an average weight of 92 to 194 pounds. One lot in each trial was given shelled corn and sweet skim milk fresh from the separator; the other lot was fed the same except that the milk had been allowed to sour. The same proportion of milk was allowed in both lots, which was from two to three parts to one of corn. The sweet and sour milk proved equally palatable, the feed consumption and rate of gain were practically identical in the two lots, and there was no difference in the amount of feed required to produce a unit of gain. Earlier studies by Cooke of the Vermont Station suggested that sour skim milk is slightly superior to sweet skim milk for young pigs.

WHEY

In general whey may be regarded as what is left of whole milk after most of the casein and fat have been removed in cheese making. What remains of the protein after the curd has been taken is mostly albumin, which constitutes about one-fifth of the protein of whole milk; the other four-fifths are in the casein. The amount of the fat of milk which remains in the whey varies according to the type of cheese made and the percentage of fat contained in the milk used, the average being about 0.36 percent. Swiss-cheese whey is highest in fat, American-cheese whey next, while the whey from the manufacture of cottage cheese is least, having practically none.[16]

This fat is now generally separated out before the whey leaves the factory by returning it through a whey separator, which has the effect, of course, of reducing the feed value of the whey. Day [17] reports that ordinary whey was worth 25 percent more for pigs than whey that had been separated. The calcium or lime content of whey is about one-third what it is in skim milk.

Whey is more watery than skim milk or buttermilk and the dry matter which it contains is much less rich in protein. Its nutritive ratio averages 1 to 6.8, while for buttermilk and skim milk it is 1 to 1.5. As a result mainly of the difference in protein and calcium content, whey is less effective in balancing the food deficiencies of the grains than is either skim milk or buttermilk.

The quantity of whey required to equal 1 pound of concentrates in

[16] L. L. VanSlyke and C. A. Publow, *The Science and Practice of Cheese Making*, Orange Judd Co., 1921.

[17] G. E. Day, *Productive Swine Husbandry*, J. B. Lippincott Company, Philadelphia, 1922.

the production of gains with growing and fattening pigs has been studied by Day of Ontario and Henry of the Wisconsin Station.[18] Day fed from 2½ to 6 pounds of whey with each pound of a meal mixture composed of small grains and wheat shorts. The average of seven trials gave an average of 744 pounds of whey as equivalent to 100 pounds of meal. Henry fed from 2 to 10 parts of whey with each pound of a combination of equal parts of corn and shorts. The average of 10 trials showed 758 pounds of whey to have the value of 100 pounds of meal.

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[18] W. A. Henry, An. Rpt., 1891.
[19] F. B. Morrison, Bul. 319 and 323, 1920.
[20] G. Bohstedt and J. M. Fargo, Bul. 435, 1936.

compared with tankage alone. The combination of equal parts cheese meal and tankage proved superior to either alone.

Rules to observe in feeding milk products. When feeding any of the milk products, it is more important to observe the rules of good feeding practice than it is with most other feeds. Because of their great palatability, young pigs up to the weight of 65 pounds especially are prone to take more than they can digest when the supply is unlimited. The result is scours, which mean a setback in the gains, a loss of feed, and a serious weakening of the digestive powers if repeated. Extension workers have reported that trouble from scours in skim-milk feeding could be greatly reduced if, instead of feeding the milk and concentrates together as a slop, as commonly is the practice, the milk is fed separately and the concentrates fed dry in the self-feeder.[21] It is important also that the feedings be at regular intervals, that the milk be nearly the same in age or degree of sourness from day to day, and that more than the usual attention be given to keeping troughs, pails, and cans in decent and clean condition. To make certain that the smaller pigs get their share of milk, extra trough space should be available. The use of sour, filthy feeding utensils, along with careless and irregular habits in feeding, may counteract entirely the benefits which we normally expect in the use of these superior feeds.

The laws of most states now require that milk by-products be pasteurized before leaving the creamery or factory. This means usually the subjection of the milk to a temperature of 145°F for 30 minutes. This temperature in no way affects the availability of the calcium or phosphorus or any of the other food factors.[22] Pasteurization is desirable, especially to guard against tuberculosis, which will develop in pigs fed unpasteurized milk coming from infected herds, although the disease rarely develops to the stage where detection in the live animal is possible. Federal inspection after slaughter may result in the condemnation of the carcass in whole or part. In 1949, 5.57 percent of the carcasses of all hogs slaughtered in the United States were "retained" because of localized lesions due to tuberculosis, resulting in affected parts being condemned for human food. In 1941 the percentage was 8.24. Only in 0.032 percent of the carcasses, however, was the disease so generalized as to necessitate the condemnation of the whole carcass.[23]

[21] J. W. Schwab, Information to the author, 1934.
[22] W. E. Krauss, J. H. Erb, and R. G. Washburn, Ohio Exp. Sta., Bul. 518, 1933.
[23] H. R. Smith, *Nat. Live Stock Loss Prevention Board*, An. Rpt., 1949, Data, U.S. Division of Meat Inspection.

An experiment conducted at the Iowa Station [24] demonstrated conclusively that pigs fed skim milk containing the germs of tuberculosis may in a relatively short time develop the disease sufficiently to necessitate condemnation of the carcasses for food. One lot of 40 pigs was fed skim milk, with grain, which had been inoculated with virulent bacilli of tuberculosis. Another similar group was fed the same infected milk in the same quantity, but after it had been pasteurized at a temperature of 200°F. At the end of the test period of 196 days both lots appeared equally healthy, although the group which received the pasteurized milk had gained a little faster. The postmortem inspection, however, gave the following results: Of the 40 pigs fed the tuberculosis milk, all were affected with tuberculosis; of the 40 which received the pasteurized milk, only two were infected. In the tuberculosis group only two of the carcasses were fit for human consumption, 45 percent were fit only for lard, and 25 percent were unfit for any food or food product.

SEMISOLID AND DRIED BUTTERMILK

Semisolid, or condensed, buttermilk, as the name implies, is buttermilk that has had its water content reduced by evaporation until the solids are about three times what they were in the buttermilk. Fluid buttermilk has about 9 percent of solids and 91 percent of water; semisolid or condensed buttermilk has 25 to 33 percent solids and 67 to 75 percent water. Adding two parts of water to one part of the semisolid product dilutes it to the same concentration as fluid buttermilk. Dried or powdered buttermilk is the product obtained by evaporating buttermilk to a concentration of 10 to 1; that is, it contains 10 times as much solids as buttermilk, running 90 to 95 percent of solids and 5 to 10 percent of water. Unlike dried skim milk, practically all the semisolid and dried buttermilk manufactured in this country is used in livestock feeding.

as is known, the effect of the lactic acid on digestion is beneficial rather than harmful. To guard against deterioration after the can has been opened, the exposed surface should be kept covered with about 1 inch of water. Due to its low water content and acidity, dried buttermilk will keep almost indefinitely under good storage conditions.

Semisolid and fluid buttermilk compared. From what has been said of the composition of the condensed buttermilk products, we have every reason to believe that their feeding value, on the dry-matter basis, would be practically the same as that of buttermilk. We will consider now briefly what the results of experimental feeding tests show. Ferrin and McCarty of the Minnesota Station [26] have made two such trials in each of which four lots of 10 pigs were fed from a weight of 75 to 175 pounds under pasture conditions. Each lot was fed shelled corn and red dog flour and either tankage, fresh creamery buttermilk, semisolid buttermilk, or dried buttermilk, in addition. The results, which were consistent in the two trials, are averaged and shown in Table 118.

Table 118. Semisolid and Dried Buttermilk versus Buttermilk and Tankage
(Average 2 Experiments)

Rations	*Initial Weight*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
Corn + red dog flour + *tankage*	*75*	*1.12*	Corn	273
			Red dog	*74*
			Tankage	23
Corn + red dog flour + buttermilk	75	1.21	Corn	248
			Red dog	68
			Buttermilk	382
Corn + red dog flour + semisolid buttermilk	75	1.21	Corn	240
			Red dog	67
			Semisolid buttermilk	108
Corn + red dog flour + dried buttermilk	75	1.21	Corn	247
			Red dog	68
			Dried buttermilk	34

On the rations balanced with the milk products the rate of gain for the three lots was the same. In economy of gains, the results showed 1 pound of semisolid buttermilk to be equivalent to 3½ pounds of creamery buttermilk in producing a given gain; and 1 pound of dried buttermilk to be equal to 10.3 pounds of creamery buttermilk. At the

[26] E. F. Ferrin and M. A. McCarty, Mimeo. H-18, 1924.

prices current at the time, however, the actual money cost of the gains was higher for the semisolid and dried buttermilk rations than for either the creamery buttermilk or tankage rations. Based on these results, which conform closely to expectation based on their actual food content, it would appear that the price of these products must come down considerably before their use in pig feeding will become general.

An experiment by Kuhlman and Wilson of the South Dakota Station [27] also demonstrated that these two feeds are efficient, but not worth the price usually charged when the more commonly used supplements are available. In these tests a pound of semisolid buttermilk had the value of 3.2 pounds of creamery buttermilk; and a pound of dried buttermilk the value approximately of 6 pounds of buttermilk. One of their comparisons suggested that semisolid buttermilk might be profitably used as a partial supplement with tankage.

Semisolid buttermilk and tankage compared. Vestal of the Indiana Station [28] compared semisolid buttermilk with tankage and fresh creamery buttermilk in two experiments. The results both in rate and cost of gain were in favor of the tankage and fresh buttermilk rations. In two trials at the Kansas Station [29] by McCampbell, Ferrin, and Winchester, semisolid buttermilk did not produce as economical gains as tankage. In three experiments at the Nebraska Station, Gramlich and Jenkins [30] compared semisolid buttermilk with tankage for fattening fairly well-grown pigs. Although the pigs which received the semisolid buttermilk gained faster, the feed requirement and money cost of the gains were considerably greater than with the tankage ration. These results coincided closely with those obtained by Grimes and associates at the Pennsylvania Station, and those of Weaver at the Missouri Station [31] when the pigs had access to rape pasture.

In all, 10 comparisons have been made here of semisolid buttermilk and tankage, four in the dry lot and six on rape forage. In 7 out of the 10 trials the pigs receiving the semisolid buttermilk gained faster. On the other hand, the cost of a unit of gain in money was less in all cases with the tankage rations. On the average, in these experiments 1 pound of tankage had the value of 3.17 pounds of semisolid buttermilk.

Dried buttermilk compared with tankage. Dried buttermilk was compared with tankage as a supplement to milo chop and shorts for fall pigs by Williams and Warren of the Texas Station.[32] The tankage contained 63 percent of protein and the dried buttermilk 33 percent. The amount of supplement fed in each lot was such as to make the protein content of the two rations the same. Although the lot which received the dried buttermilk made their gains on less feed, the cost of the gains in dollars and cents was considerably greater. The authors stated that considerable care was necessary in getting the pigs accustomed to this feed without scouring them.

At the Iowa Station Evvard and Dunn [33] self-fed 11 pairs of spring pigs shelled corn supplemented with tankage and buttermilk powder (dried buttermilk). The tankage was high-grade and the dried buttermilk analyzed 30 percent of protein. The corn was self-fed in one compartment of the feeder and the mixture of tankage and dried buttermilk in a second compartment. One pair was self-fed tankage alone, a second pair a mixture of 90 percent tankage and 10 percent dried buttermilk. The remaining pairs were given increasing percentages of dried buttermilk. The pigs were confined to the dry lot and each pair fed from the average beginning weight of 50 pounds to a final weight of 225 pounds. Block salt was accessible to all lots.

As the proportion of dried buttermilk to tankage was increased there was a tendency for the rate of gain slightly to increase, especially up to the point where it constituted one-half the combination. The tankage proved more palatable than the dried buttermilk. Based on the amount of feed required to produce a given gain, 100 pounds of the dried buttermilk had the value of 76 to 85 pounds of tankage, depending on the base used in the calculations.

Similar results were obtained by Ferrin of the Minnesota Station [34] in an experiment conducted in the winter of 1944 to 1945. He fed 72-pound pigs to weights of about 210 pounds on three types of protein supplements, self-fed, in addition to corn and minerals, composed as follows:

Lot I—Tankage 35 percent, soybean oil meal 35 percent, and alfalfa leaf meal 30 percent.

Lot II—Dried buttermilk 35 percent, soybean oil meal 35 percent, and alfalfa leaf meal 30 percent.

[32] D. W. Williams and G. R. Warren, Bul. 305, 1923.
[33] J. M. Evvard and R. Dunn, *Mimeo. Rpt.*, 1918.
[34] E. F. Ferrin, Mimeo. H-90, 1946.

Lot III—Dried buttermilk 20 percent, tankage 25 percent, soybean oil meal 25 percent, and alfalfa leaf meal 30 percent.

The average daily gains for the pigs in the three lots were, respectively, 1.60, 1.67, and 1.65 pounds. The total feed consumed for each 100 pounds of gain was respectively 377, 373, and 366 pounds. Considering feed prices, the author concluded that the cost of gains was raised when 20 percent or more of dried buttermilk was fed in the protein mixture.

Since dried buttermilk contains but little more than one-half as much protein as high-grade tankage, the results of all these experiments suggest a high supplementing efficiency for this milk product.

Powdered skim milk and tankage compared. Smith and Maynard of the Utah Station [35] compared these two supplements when fed to pigs from a weight of 45 to near 200 pounds on alfalfa pasture. The skim-milk powder analyzed 38 percent protein and 50 percent sugar; the tankage 60 percent protein. These supplements were self-fed, free-choice, with either ground barley or ground wheat, self-fed, and salt. The results, together with those for one lot of pigs which received no protein concentrate, are summarized in Table 119.

Table 119. Powdered Skim Milk versus Tankage for Pigs on Alfalfa Pasture
(Average 6 Experiments)

Rations	*Initial Weight per Pig*	*Concentrates Consumed Daily per Pig*	*Daily Gain per Pig*	*Concentrates Required Each 1 Cwt. Gain*	
	lb.	lb.	lb.		lb
Gr. wheat or barley + salt	45	5.02	1.27	Grain	395
				Salt	0.42
				Total	395.42
Gr. wheat or barley + skim milk powder + salt	45	5.20	1.41	Grain	336
				Skim milk powder	33
				Salt	0.27
				Total	[illegible]
Gr. wheat or barley + tankage + salt	45	5.21	1.37	Grain	[illegible]
				Tankage	[illegible]
				Salt	[illegible]
				Total	[illegible]

[35] H. H. Smith and E. J. Maynard, Bul. [illegible], [illegible]

When fed either with the wheat or barley, the pigs which received skim-milk powder gained slightly faster than those fed the tankage and made 100 pounds of gain on considerably less feed. Because of the price of the dried milk and the amount of it consumed, however, the money cost of the gains was less for the tankage ration.

The same investigators [36] in one winter experiment compared skim-milk powder alone with a supplement composed of equal parts skim-milk powder and tankage, and one of tankage alone for 45-pound pigs fed to market weight. The other components of the ration were ground wheat, self-fed, free-choice, alfalfa hay, and salt. The supplements were self-fed, free-choice. The two lots fed the skim-milk powder alone or the combination of skim-milk powder and tankage made faster gains than those which received tankage alone as the supplement by the difference between 1.45 and 1.25 pounds daily per pig. The cost of the gains, however, was less in the lot fed tankage alone than in either of the other two.

Hughes and Ittner of the California Station [37] secured better results from reconstituted skim milk, made by adding water to the skim-milk powder in an amount to equal that contained in fluid skim milk, than from the same product fed dry. Also, they concluded that skim-milk powder produced by the spray method of drying seemed slightly superior to that dried by the roller or drum process.

Conclusions. The results of these feeding tests indicate that the solids contained in the concentrated milk products have suffered no less in food efficiency as a result of the manufacturing processes which produced them. One pound of semisolid buttermilk was shown to be equal to 3 to 3.5 pounds of fluid buttermilk; in other words, their values are about in proportion to the amount of solids contained. In the 10 trials in which semisolid buttermilk and high-grade tankage were compared, 3.17 pounds of the former were shown to have the value of 1 pound of the latter. Although the conclusion is clear that these milk products are splendid feeds, it is equally evident that the practical feeder cannot afford to feed them until their prices are reduced more nearly to the level of that of the other supplements.

SOME TYPES OF RATIONS CONTAINING MILK BY-PRODUCTS

For fall pigs during the winter. 1. Corn or other grain, self-fed, + tankage or other high-grade supplement, self-fed, until the pigs

[36] *Ibid.*
[37] E. H. Hughes and N. R. Ittner, Bul. 661, 1942.

have reached a weight of 75 pounds + 2 to 4 quarts of skim milk or buttermilk daily while they are getting tankage and nearly all they will take thereafter if available + green alfalfa meal fed mixed with the tankage in the ratio of 2 to 1 in the self-feeder or mixed with the other concentrates in an amount to make it 10 percent of the dry ration. Although the mineral requirements are fairly well taken care of by this ration, a better balanced supply of the elements needed will be ensured by self-feeding a mixture, such as equal parts of limestone dust, special steamed bone meal, and common salt, by weight.

2. When the supply of milk is limited or the price relatively high, feed the same as Ration 1, but continue to feed the tankage or other dry protein supplement, which was fed while the pigs were below 75 pounds in weight, for the entire time.

3. When one part of semisolid buttermilk has added to it 2 to 2¼ parts of water, it is reduced to the same concentration as good buttermilk or skim milk. When thus diluted it may be substituted for skim milk or buttermilk, pound for pound, when available at reasonable prices. Because of its tendency to cause scours when fed liberally, great care should be taken to accustom the pigs to it gradually in the beginning. To avoid this trouble some feeders recommend greater dilution than 1 to 2 parts water. It is perhaps most effectively used when fed as a partial supplement along with another protein feed.

For full-fed spring pigs on forage. Pigs on good forage ordinarily should not be fed much more than one-half the amount of milk which would be appropriate in dry-lot feeding. When the supply is limited below this amount, maximum gains will be ensured by feeding in addition a dry protein supplement in the self-feeder. For limited-fed pigs on good forage, no supplement is necessary (see Chapter X, page 285).

For pregnant sows during the winter. For mature sows, feed corn or other grains in an amount to secure a gain approximately of 75 to 100 pounds during the winter, which will be 1 to 1½ pounds of dry feed daily for each hundredweight of sow, + 2 to 4 quarts of milk daily + fine-quality green legume hay in a rack, or fed as a meal mixed with the concentrates in an amount to make it about 10 to 15 percent of the grain mixture + a suitable mineral mixture self-fed during the last half of the gestation period. For young sows carrying their first litters, the desirable growth and gain in weight will be secured by feeding from 1⅔ to 2 pounds of concentrates daily for each hundredweight + 1 gallon skim milk or buttermilk daily. The

unlimited feeding of milk is not advisable; not only is it wasteful of feed and unnecessary, but is likely to result in soft overdeveloped pigs, which lack the vigor necessary to their survival at birth (see Chapter III, page 62).

For sows nursing pigs. Skim milk and buttermilk have special value when fed judiciously to sows in milk. Do not give the sow much milk until her pigs are two to three weeks old. After she has been brought up to full feed, increase gradually the amount of milk until she is receiving 1 to 1½ gallons daily. With no other protein supplement in the ration, she may be fed 2 gallons a day (see Chapter IV, page 99).

For the boars. Skim milk and buttermilk are especially valuable for boars during the breeding season. As much as 1½ gallons a day will not be excessive. Best results will be obtained, however, when it is fed in conjunction with a mixed ration, such as 35 percent ground corn, 30 percent ground or rolled oats, 30 percent wheat middlings, and 5 percent tankage, with 1 to 1½ gallons of milk daily. For yearling and mature boars not in service, 1 gallon of milk daily will supply sufficient protein when fed in a mixed grain ration (see Chapter II, page 28).

XIII Protein Supplements—Packing House and Similar Products

Among the useful by-products of the slaughtering and meat-packing industry which science and ingenuity have made available are those which include the animal feeds. What once was waste to be disposed of as sewage later became a fertilizer, and then a feed. The big packers seriously started selling tankage and other animal feeds about 1900. Since then these feeds have passed successfully through the early experimental stages of manufacture and use, and now are generally recognized by hogmen as among the most valuable supplements available to the feeder, rich in those constituents especially needed to balance the deficiencies of corn and other home-grown grains.

TANKAGE; MEAT SCRAPS

Tankage is composed mainly of the residues of the lard, tallow, and grease tanks, plus varying amounts of blood and evaporated tank water or "stick." These residues consist not only of the scrap from the lard-rendering tanks, but include also what is left after the fat and grease have been removed from various inedible animal tissues. These include scraps of meat and bone, portions of some of the vital organs, cleaned viscera, carcasses which have failed to pass government inspection, and portions of animals which have died at the yards or in transit, not including the hide, horns, hoofs, or stomach contents.

Methods of manufacture. In the old, or wet-rendering, process this material is cooked in live steam under a pressure of 20 to 60 pounds to the square inch for a period usually of about 8 hours.[1] This is sufficient to thoroughly disintegrate the material, to remove most of the fat, and to render the product strictly sterile. After the fat has been drawn off and most of the water removed, the contents are subjected to

[1] H. R. Kraybill, Poultry Science, Vol. VIII, No. 1, [illegible]

hydraulic pressure and then dried, finely ground, and screened. This is wet-rendered tankage and will analyze 33 to 42 percent of protein. Instead of selling this "mine-run tankage" as such, however, the usual practice in the large plants is to build up the protein content to about 60 percent by the addition of commercial tank water, called stick, or blood, or both.[2] Most of the tankage manufactured by the smaller plants is not built up and hence contains only 35 to 40 percent of protein.

In the new or dry-rendering process the material is heated in steam-jacketed horizontal tanks for 3 to 8 hours. No water is added and the material is continually stirred by a mechanical agitator. The steam produced from its own moisture is allowed to escape through the vents when it reaches a certain pressure. After the fat and grease have been drawn off, the residue is passed through an expeller to remove the fat more completely. The material as it comes from the expeller is called cracklings. After grinding and screening the product is known as meat scraps, or meat and bone scraps, depending on the amount of bone present.[3] Meat scraps are strictly a dry-rendered product and will generally analyze 50 to 55 percent of protein; meat and bone scraps will average about 50 percent protein. Some plants, however, produce a 60 to 65 percent grade of meat scraps by using only the better quality raw materials in its manufacture. Supermeat scraps, running up to 75 percent of protein, are produced when the cracklings are composed largely of degreased fatty tissues.[4]

Kraybill reports that the dry-rendering process is used by packers mainly for the cattle and sheep by-products, by some dead animal-rendering plants, and by most city melters. Since the fat obtained is of better quality, the odors produced less objectionable, the loss of ammonia less, and the cost more economical, the process is increasingly used in handling the inedible products. Owing to Board of Trade regulations, however, packers feel that they must continue to use the wet-rendering method in the production of prime steam lard.

That the dry-rendering process is replacing the old wet-rendering method as rapidly as new machinery is added is indicated by the results of Vestal's study.[5] On the basis of the type of rendering used

[2] Paul I. Aldrich, The Packers Encyclopedia Blue Book, National Provisioner Pub. Co., Chicago, 1922.

[3] H. R. Kraybill, Poultry Science, Vol. VIII, No. 1, Nov., 1928.

[4] P. B. Curtis, S. M. Hauge, and H. R. Kraybill, *Jour. of Nut.*, Vol. V, No. 5, Sept., 1932.

[5] C. M. Vestal, An. Rpt., *Proc. Am. Soc. An. Prod.*, Jan., 1930.

for inedible residues, the 140 packing plants questioned were classified as follows: 59 plants used the wet-rendering method only, 50 used the dry-rendering method only, 23 plants were changing from the wet- to the dry-rendering method, and 8 plants were using both the wet- and dry-rendering process.

Definitions. There is still considerable confusion relative to the meaning of the brand names used to designate the several kinds of tankages and other meat by-products. In the interests of uniformity, for a better understanding on the part of the feeder, and to serve as a guide to the manufacturer in labeling his product, the Association of American Feed Control Officials have promulgated the definitions as given below.[6]

DIGESTER TANKAGE, MEAT MEAL TANKAGE, or FEEDING TANKAGE is the finely ground, dried residue from animal tissues exclusive of hairs, hoof, horn, manure, and stomach contents, except in such traces as might occur unavoidably in good factory practice, especially prepared for feeding purposes by tanking under live steam, or by dry-rendering, or a mixture of the products. When these products contain more than 4.4 percent of phosphorus, they must be designated "Digester Tankage with Bone," "Meat and Bone Meal Digester Tankage," "Meat and Bone Meal Tankage," or "Feeding Tankage with Bone." If the product bears a name descriptive of its kind, composition, or origin, it must correspond thereto. It must be designated and sold according to its protein content.

MEAT MEAL or MEAT SCRAP is the finely ground, dry-rendered residue from animal tissue exclusive of hair, hoof, horn, blood, manure and stomach contents, except in such traces as might occur unavoidably in good factory practice. When these products contain more than 4.4 percent of phosphorus (P), they shall be designated either "Meat and Bone Meal" or "Meat and Bone Scrap." If the product bears a name descriptive of its kind, composition, or origin, it must correspond thereto. It must be designated and sold according to its protein content.

Tankage, therefore, may consist of the products produced either by the wet- or dry-rendering process, or both, to which blood or stick may be added. Meat scrap, on the other hand, must consist only of the dry-rendered residues to which no stick or blood may be added.

BLOOD MEAL is ground dried blood.

[6] Ind. Exp. Sta., Cir. 351, Apr., 1949.

BLOOD FLOUR is dried blood, prepared by special processes and reduced to fine powder.

ANIMAL LIVER MEAL is the product obtained by drying and grinding liver from slaughtered mammals. This product must contain at least 27 milligrams of riboflavin per pound.

EXTRACTED ANIMAL LIVER MEAL is the product obtained by drying and grinding the residue of animal liver tissue from which a large portion of the vitamins and/or minerals have been removed.

RAW BONE MEAL is the dried ground product suitable for animal feeding, obtained by cooking undecomposed bone in water at atmospheric pressure just enough to remove excess fat and meat. It shall contain not less than 23 percent of protein.

STEAMED BONE MEAL is the dried, ground product suitable for animal feeding, obtained by cooking bones with steam under pressure.

SPECIAL STEAMED BONE MEAL is the dried, ground product suitable for animal feeding, obtained by cooking dried bones, after the removal of grease and meat fiber, with steam under pressure in the process of obtaining gelatine or glue.

BONE CHARCOAL or BONE BLACK is the product obtained by charring bones in closed retorts. It shall contain not less than 14.7 percent of phosphorus.

SPENT BONE BLACK is the product resulting from the repeated charring of bone charcoal or bone black after use in clarifying sugar solutions. It shall contain not less than 11.5 percent of phosphorus.

BONE ASH is the ash obtained by burning bones with free access to air and containing 15.3 to 16.6 percent of phosphorus.

Production of tankage and meat scraps. Official estimates by statisticians of the U.S. Department of Agriculture place the average quantity of these packing house by-products annually available from 1937 to 1947, inclusive, at 781,000 tons.[7] During this 11-year period the production varied from a low in 1937 of 608,000 tons to a high in 1943 of 975,000 tons. According to the Bureau of Agricultural Economics of the U.S. Department of Agriculture approximately 77 percent of these by-products in 1949 were dry-rendered meat scraps, and 23 percent wet-rendered tankage. Dry-rendering and the consequent production of meat scraps has to a large extent superseded the old wet-rendering process because it is a more efficient operation.[8]

[7] *Agr. Statistics*, U.S.D.A., 1948.
[8] O. H. M. Wilder, *American Meat Institute Foundation*, University of Chicago, Paper presented at Meeting of Institute of Food Technologists, May 24, 1950.

Composition of meat and marine by-products. As shown in Table 120 the meat and fish by-products are particularly rich sources of proteins and minerals. Compared with the protein feeds of plant origin, they contain much higher percentages of calcium and phosphorus, as well as of common salt. The high calcium content makes them especially valuable as supplements to the grains and when fed in combinations with supplements of plant origin. The animal and fish supplements also are less deficient in the better known water-soluble B vitamins, and are excellent sources of B12 and the other vitamins associated with the animal protein factor (APF).

Table 120. Composition of Meat and Marine By-products[a]

Feeds	*Water*	*Protein*	*Fat*	*Carbohydrates*	*Calcium*	*Phosphorus*
Tankage, digester process, 60% grade	6.9	60.6	8.5	3.8	6.37	3.23
Tankage with bone, digester process, 40% grade	5.3	42.9	14.1	6.3	13.49	5.18
Meat scraps or dry-rendered tankage, 60% grade	6.2	60.9	8.8	3.5	6.09	3.40
Meat and bone scraps, or dry-rendered tankage with bone, 45% grade	5.5	46.3	12.0	4.3	11.21	4.88
Blood meal	8.2	84.5	1.1	1.7	0.33	0.25
Liver meal, animal	7.7	66.2	16.4	3.3	0.62	1.27
Fish meal, menhaden	6.4	62.2	8.5	4.9	5.30	3.14
Fish meal, sardine	6.9	67.2	5.0	6.0	4.21	2.44
Fish solubles, condensed	50.5	29.3	8.4	2.2	•	
Shark meal	8.8	74.5	2.7	0.5	3.[illegible]	1.[illegible]
Shrimp meal	10.3	46.7	2.3	12.4		

method. This tankage is often referred to as "dead-animal" tankage or "reduction" tankage. Vestal reported that there were 130 such plants in Indiana in 1930. The third grade, which analyzes from 35 to 50 percent protein, is the ordinary tankage, usually produced by the wet-rendering method, which has not had its protein content built up by the addition of any stick or blood. This is the kind usually produced by the smaller packers and is often referred to as "special" feeding tankage. Because of its high bone content it is often officially designated as "digester tankage with bone," "meat- and bone-meal digester tankage," or "feeding tankage with bone."

Vestal of the Indiana Station [10] made a rather thorough study of these three grades of tankages. In each of three summers three lots of 10 pigs each were hand-fed a combination of ground corn and tankage on legume pasture. One lot was fed the high-grade, or Number 1, tankage in the ratio of 1 part of tankage to 12 parts of corn; the second lot received the 50 percent grade reduction tankage in the ratio of 1 part to 9½ parts of corn, while the third lot received 1 part of the "special" tankage to 8 parts of corn. The summarized results of these trials are shown in the upper division of Table 121. The pigs averaged 65 pounds in weight when the experiments began and were fed in each case to market weight.

In the lower division of the table are given the averaged results from four years' experiments with the same feeds fed under exactly the same conditions except that the corn and tankage were fed separately *in a self-feeder, free-choice style.*

As one would expect, when corn and tankage was fed to pigs on good legume pasture, excellent gains were made in all lots in these trials. On the basis of actual composition and prices paid, the two lower grades of tankage used were cheaper in costs; that is, the cost of a pound of protein was considerably less than in the Number 1 tankage. In other words, there was a greater spread in the prices than was justified by the actual feeding results or the differences in protein content.

A safe but rough general rule in deciding which of two grades of tankage is cheaper at given quoted prices is to rank them according to the cost of a pound of protein, after giving to each due credit for the fat they contain, valued at the price of its food equivalent in corn or other grain. It is important to consider this difference in fat content because the higher the protein content, the lower will be the fat con-

[10] C. M. Vestal, A. H. Mimeo. Rpts., 1926, 1927, 1930.

Table 121. Different Grades of Tankages Compared for Pigs on Legume Forage
(Average 3 and 4 Experiments)

Rations	*Daily Ration*		*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
		lb.	lb.		lb.
Ground corn 12 + regular tankage (62%) 1, mixed and self-fed	Corn Tankage	5.73 0.47	1.680	Corn Reg. tankage	341 28
Ground corn 9½ + reduction tankage (50%) 1, mixed and self-fed	Corn Red. tankage	5.72 0.62	1.733	Corn Red. tankage	330 36
Ground corn 8 + special tankage (42%) 1, mixed and self-fed	Corn Sp. tankage	5.64 0.70	1.673	Corn Sp. tankage	337 42
Shelled corn; regular tankage (63%), self-fed, free-choice	Corn Tankage	5.59 0.38	1.640	Corn Reg. tankage	341 23
Shelled corn; reduction tankage (53%), self-fed, free-choice	Corn Red. tankage	5.51 0.38	1.669	Corn Red. tankage	330 23
Shelled corn; special tankage (40%), self-fed, free-choice	Corn Sp. tankage	5.22 0.31	1.562	Corn Sp. tankage	334 20

tent. The Number 1 tankage used in the experiments above contained on the average 8.5 percent of fat, while the special tankage with 40 percent of protein contained 15.5 percent. This extra fat in the lower grade product has food value and obviously should be credited. The most accurate method of valuing this is to compute it according to the price of its food, or carbohydrate, equivalent in corn, which it actually replaces in the ration.

This method assumes that the supplementing value of a pound of protein in the high- and low-grade tankages is the same. As a matter of fact, there is good evidence suggesting that the proteins of the lower grade tankages have a higher supplementing efficiency when fed with corn than do the proteins of the higher grades, which have been built up by the addition of stick. This was shown rather clearly by Curtis and associates of the Indiana Station [11] in feeding experiments with rats. The stick, or concentrated tank liquor, composed as it is very largely of hot-water-soluble proteins, was found to be especially deficient in the amino acids tryptophane and cystine, the two particular

[11] P. B. Curtis, S. M. Hauge, Henry R. Kraybill, *Jour. of Nut.*, Vol. V, No. 5, Sept., 1932.

proteins especially needed to balance corn. It would appear, therefore, that a small further credit is due to the lower grade tankages because of a slight superiority in the quality of their proteins.

The lower the grade of tankage, the higher also is its mineral or bone content, as a rule. No particular credit is due to this extra bone, however, because it is in excess of the amount needed to meet the demands of the pig. In other words, the high-grade tankages, containing 60 percent or more of protein, usually contain sufficient bone to ensure an adequate supply of calcium when fed in the amount necessary to balance the grain in protein.

Meat and bone scraps compared with tankage. In Table 122 are summarized the results of seven experiments in which standard tankage was compared with meat and bone scraps for spring pigs on forage. The tankage was the high-grade variety which had had its protein content built up by the addition of stick, or stick and blood. That actually used in the trials analyzed 61 percent of protein. The meat and bone scraps used were the usual strictly dry-rendered product and without the addition of any stick or blood and averaged 51 percent of protein (see page 165). There was very little variation in

Table 122. Tankage versus Meat and Bone Scraps for Pigs on Legume Forage
(Average 7 Experiments)

Rations	*Daily Ration*		*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
		lb.	lb.		lb.
Corn + tankage (61%)	Corn	5.31		Corn	316
	Tankage	0.42	1.681	Tankage	25
	Total	5.73		Total	341
Corn + meat and bone scraps (51%)	Corn	5.22		Corn	311
	Meat and bone scraps	0.44	1.680	Meat and bone scraps	26
	Total	5.66		Total	337

the quality of either feed in the different trials. In all excepting the Minnesota trial, the two feeds were purchased at the same price a ton. Six of the experiments were run at the Indiana Station [12] and one at the Minnesota Station.[13] The pigs averaged 68 pounds when the tests began and around 200 pounds at the finish. In two of the trials the

[12] C. M. Vestal, A. H. Mimeo. Rpts., 1929, 1930, 1931, and 1932.
[13] E. F. Ferrin, Mimeo. H-58, Oct., 1933.

corn and supplement were self-fed, free-choice, in four these feeds were combined in definite proportions and self-fed, and in one they were mixed and hand-fed according to appetite. The pigs were on alfalfa in five of the trials, on clover in one, and on rape in one.

In none of the individual experiments summarized in the table was there a difference either in the rate or cost of gains sufficient to be considered important. The average rate of gain was practically identical. In efficiency, a pound of the meat and bone scraps was clearly equal to a pound of the tankage despite the fact that there was supplied in each 100 pounds of the former 10 pounds less of protein. This may be taken as evidence that the protein contained in meat and bone scraps had a somewhat higher supplementing efficiency.

Vestal also compared Number 1 tankage, analyzing 60 percent of protein, with meat and bone scraps, analyzing 51 percent, under dry-lot conditions in two trials. The supplements were fed free-choice style and the experiments covered the period from the beginning weight of 72 pounds to a market weight approximately of 200 pounds. Although the tankage was nearly 10 percent richer in protein, slightly more of this supplement in proportion to corn was consumed than of the meat and bone scraps, the ratio being 1 part of meat and bone scraps to 7.7 parts of corn in the tankage ration and 1 part of meat and bone scraps to 8.15 parts of corn in the latter ration.

The average daily gains were 1.72 pounds on the tankage ration and 1.82 on the meat- and bone-scraps ration. The amount of feed required for each 100 pounds of gain, however, was slightly less for the lots receiving tankage, the averages being 350 and 356 pounds, respectively. We should conclude from these trials also that 1 pound of the meat and bone scraps was practically equal in value to 1 pound of Number 1 tankage.

In two trials at the Ohio Station Robison [14] compared dry-rendered tankage (meat scraps) containing 60 percent of protein with digester or wet-rendered tankage under dry-lot conditions. In both instances the dry-rendered product proved slightly more valuable; the gains were faster and the feed consumed for a unit of gain was somewhat less.

Dry- and wet-rendered tankage compared. Johnson of the Minnesota Station [15] made nine feeding tests in an experiment to determine the relative feeding value of wet- and dry-rendered tankage for pigs

[14] W. L. Robison, Spl. Cirs. 32 and [illegible], [illegible] and [illegible].
[15] D. W. Johnson, Mimeo. H-73, [illegible].

fed in the dry lot. In trials to determine the palatability of the two feeds, he found that nursing pigs, 50-pound pigs, and 100-pound pigs all showed a decided preference for the dry-rendered tankage. In other tests in which equal amounts of the two supplements were fed, faster growth was secured with the dry-rendered product. On the whole he concluded: "The differences in palatability and quality of the proteins are undoubtedly both responsible for the decidedly greater feeding value of dry-rendered tankage as was shown by each of four separate feeding tests involving four different purchases of each tankage."

In four trials dry-rendered tankage and meat and bone scraps were compared for growing pigs in the dry lot, both supplements self-fed, free-choice. Although there was little if any difference in palatability, the dry-rendered tankage in all cases showed a higher feeding value than the meat and bone scraps.

Improving a ration of corn and tankage. In Table 123 are summarized the results of six dry-lot feeding trials with growing and fattening pigs showing the effect of replacing part of the tankage in a corn-tankage ration with skim milk. Three of the experiments were run at the South Dakota Station [16] and three at the Ohio Station.[17] Each trial covered the growing and finishing period from a beginning weight of about 50 pounds to a final weight of 200 pounds.

The results as averaged in the table were consistently shown in the individual experiments. The faster rate of gain made by the pigs which received the skim milk in addition to the tankage was due mainly to the greater palatability of the ration and the larger feed consumption. Part of it, however, must have been the result of superior supplementing efficiency; for the feed consumption of the skim milk

Table 123. Adding Skim Milk to a Corn-Tankage Ration
(Average 6 Experiments)

Rations	*Daily Feed Consumption*		*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.		lb.	lb.	
Corn + tankage	Corn	4.15	1.122	Corn	370
	Tankage	0.41		Tankage	37
Corn + tankage + skim milk	Corn	4.46	1.443	Corn	309
	Tankage	0.26		Tankage	18
	Skim milk	4.15		Skim milk	288

[16] Arthur H. Kuhlman and James W. Wilson, Bul. 216, 1925.
[17] W. L. Robison, Spl. Cirs. 32 and 39, 1918 and 1932; Bul. 488, 1931.

ration was only 14 percent in excess of that of the tankage-alone ration, while the rate of gain was 28 percent greater.

As shown by the results summarized in Table 114, a combination of tankage and buttermilk proved superior to buttermilk alone for balancing corn. It would appear, therefore, that a combination of tankage and skim milk or buttermilk is superior to either alone. Apparently, the improvement which results is due principally to enhanced palatability and partly to the presence in the milk ration of certain desirable vitamin factors and amino acids not contained in adequate amounts in the other ration. For dry-lot feeding, however, neither is complete, especially for young pigs.

Alfalfa hay improves a corn-tankage ration. In each of nine experiments conducted at the Nebraska, Wisconsin, Kansas, and Ohio Stations one lot of pigs was fed a ration of corn and high-grade tankage, and a second comparable lot the same with alfalfa hay. In three of the trials the alfalfa was fed in the long condition in racks; in the other six it was chopped and mixed with the tankage. In all cases the feeds were self-fed, or hand-fed according to appetite. The pigs were confined to dry lots, averaged 70 pounds in weight when the experiments started, and were fed in each instance to market or near-market weights. The summarized results are shown in Table 124.

Table 124. Tankage versus Tankage Plus Alfalfa Hay for Balancing Corn in Dry Lot
(Average 9 Experiments)

Rations	*Daily Feed Consumption*		*Daily Gain*	*Feed Required to Produce 1 Cwt. Gain*	
		lb.	lb.		lb.
Corn + tankage	Corn	4.34		Corn	408
	Tankage	0.44	1.063	Tankage	41
	Total	4.78		Total	449
Corn + tankage + alfalfa hay	Corn	4.49		Corn	360
	Tankage	0.45	1.181	Tankage	34
	Alfalfa hay	0.20		Alfalfa hay	17
	Total	5.14		Total	415

Although the amount of hay consumed was less than 4 percent of the ration, its effect was to increase feed consumption and the rate of gain. Here is further evidence that there is contained in fine-quality green hay certain essential vitamin factors which the corn-tankage

ration lacks in adequate amounts. Pigs fed corn and tankage alone, without green feed of any kind, often become stiff and show other evidences of malnutrition toward the end of the feeding period, especially during the winter months (see page 200).

Liver meal. That unextracted animal-liver meal contains some unidentified factor or factors which confer nutritional benefits when added to many so-called well-balanced rations is indicated by the studies of a number of investigators. Especially is this the case with young pigs up to a weight of 100 pounds, or of those lacking thrift.

At the Cornell Station, Willman and Morrison [18] conducted seven dry-lot experiments from 1939 to 1942 in which animal-liver meal was fed as 2.5 percent of the ration until the pigs reached 100 pounds, 1.25 percent from 100 to 150 pounds, and 1 percent from 150 pounds to market weight, in addition to the ration of ground yellow corn, standard wheat middlings, tankage, 0.125 pound of cod-liver oil per 100 pounds of the mixture, a mineral mixture, and salt. These ingredients were mixed and self-fed. In most of the trials the liver meal represented the residue of fresh livers from which the antianemic factor had been extracted with boiling water. They estimated that about one-half of the water-soluble vitamins was also removed in the process.

In each of these seven trials the pigs which received the small allowance of liver meal in addition to the check ration consumed more feed and made significantly faster gains. The average daily gain for those that received liver meal was 1.43 pounds, while those on the check ration gained 1.34 pounds. The amount of feed required for a 100-pound gain was 373 pounds for those with, and 377 for those without the liver meal.

In two other experiments at the same station, conducted under similar conditions, the check ration included, in addition to the same feeds as above, 5 percent of ground alfalfa hay in place of the cod-liver oil. In these trials the pigs which received the liver meal gained 1.43 pounds daily, while those on the check ration gained 1.38 pounds. The feed consumed for each 100 pounds of gain was 370 pounds for the liver-fed pigs, and 362 for those on the check ration. These differences are not large enough to be of any significance.

Blood meal. Owing to its extremely concentrated character and high price, blood meal or blood flour is not commonly fed to pigs. It contains over 80 percent of protein, which ranks high in quality

[18] John P. Willman and F. B. Morrison, Bul. 836, 1947.

or efficiency. It is especially rich in the amino-acid tryptophane, one of two which are low in corn. Its calcium or lime content, on the other hand, is very low. It is also relatively rich in iron and, when fed in diluted quantities to anemic animals, gives good results. When fed as the chief protein supplement in a grain ration, no more than one-half as much blood meal should be fed as would be appropriate with tankage or meat scraps. Owing to its great deficiency in calcium, such a ration should always be supplemented with a mineral mixture rich in lime.

FISH MEAL

Fish meal is the general name used to designate quite a wide variety of fish products having as their source the by-products of the fishing industry. Like by-products from the meat-packing industry, variation exists between the different brands, the result both of variation in the character of the materials contained and differences in the methods employed in their manufacture. The definitions adopted by the Association of American Feed Control Officials for the marine products are given below.

Definitions. FISH MEAL is clean, dried, ground tissues of undecomposed whole fish or fish cuttings, either or both, with or without the extraction of part of the oil. If it contains more than 3 percent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 percent.

FISH RESIDUE MEAL is the clean, dried, undecomposed residue from the manufacture of glue from nonoily fish. If it contains more than 3 percent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 percent.

brand name, provided that in no case shall the salt content of this product exceed 7 percent.

SHRIMP MEAL is the undecomposed ground dried waste of shrimp and contains the head, hull, or whole shrimp, either or in mixture. If it contains more than 3 percent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 percent.

WHALE MEAL is prepared from the clean, dried, undecomposed flesh of the whale, after part of the oil has been extracted. If it contains more than 3 percent of salt (NaCl) the amount of salt must constitute a part of the brand name, provided that in no case shall the salt content of this product exceed 7 percent.

Kinds of fish meal. There are two general classes of fish meals, based on the source or character of the materials contained. The first represents the by-products coming from factories engaged in pressing or extracting the oil from nonedible fish, such as the menhaden. This is known as menhaden fish meal. The second is the by-product produced by the factories engaged in canning fish for market, mostly the sardine, cod, and haddock. The meal produced from the sardine is called *pilchard meal,* and that from the cod and haddock *white fish meal.*

MENHADEN FISH MEAL is the dried and ground residue of menhaden fish after a portion of the oil has been removed by cooking and pressing, and contains from 4 to 12 percent of oil. Pilchard meal is the dried and ground residue resulting as a by-product from the canning of the sardine and consisting of the heads, tails, and entrails after most of the oil has been extracted. It is similar in analysis to menhaden meal.

WHITE FISH MEAL is made principally from the cod and haddock, nonoily fish, and consists of the heads, backbones, fins, tails, and some flesh after they have been dried and ground. The entrails are not included.[19]

Production of fish meals. The fishing industry in the United States and Alaska produced 782 million pounds of canned fish in 1948 with an estimated value of 336 million dollars. By-products from the canneries, and those from firms engaged in the extraction of oil from nonedible fish, resulted in the production of the various types of meal suitable for feeding as shown in Table 125.[20]

[19] L. A. Maynard, R. C. Bender, and C. M. McCay, Cornell Exp. Sta., *Jr. Agr. Res.,* Vol. 44, No. 7, 1932.

[20] C.F.S. No. 497, *Canned Fish and By-Products,* 1948, U.S. Dept. of Interior, A. W. Anderson, Chief, Branch of Com. Fisheries.

Table 125. Production of Marine Scrap and Meal, 1948

Product	*Tons*
Menhaden	104,058
"White fish"	21,780
Tuna and mackerel	21,305
Pilchard	19,076
Herring	17,686
Crab	5,151
Salmon	1,152
Shrimp	724
Whale (meat and bone)	479
Fur seal	341
Anchovy	163
Shark	106
Miscellaneous	7,498
Total	199,519

Menhaden fish meal constitutes more than one-half the total production, all of which is produced on the Atlantic and Gulf coasts. All of the pilchard meal comes from factories situated on the Pacific coast.

The use of fish meal as a feed rather than as a fertilizer did not become common in this country until about 30 years ago. Orr and Crowther [21] report that its general use in England began about 1916. Since 1920, there have accumulated a considerable amount of data indicating the superior feeding qualities of fish meal as a protein-rich supplement. The general composition of most varieties is very similar to that of tankage and meat scraps.

Fish meal and tankage compared. A summary of the experiments carried out by the stations of the country, the results of which were published prior to 1937, in which high-grade tankage and menhaden fish meal were compared as supplements to corn for growing and fattening pigs in the dry lot, showed a slight superiority for the fish meal both in the rate and economy of gains. The differences, however, were not large. In a majority of the experiments the actual money cost of 100 pounds of gain was less for the fish-meal ration, although in most cases the tankage was purchased at a lower price. In these trials, the fish meal was worth $5 to $10 a ton more than the tankage. During this same period, the same rations were compared in four experiments with pigs on rape pasture. Here again the fish meal was slightly though not significantly superior to the tankage.

[21] J. B. Orr and C. Crowther, *Jr. Ministry of Agr.*, Vol. 35, No. 5, 1928.

Hackedorn and Sotola of the Washington Station [22] compared fish meal produced by the canneries of the Pacific coast with tankage in five experiments. The fish meal averaged 56 percent of protein and the tankage 60 percent. Although similar in composition, this is a different type of fish meal than that used in the experiments just considered. The ration consisted of three parts rolled barley and one part of "mill run" made up of finely ground shorts, bran, and middlings, with either fish meal or tankage, and was hand-fed according to appetite. In three of the trials the pigs were in dry lots, and in two on forage. In these experiments the fish meal proved to be about 14 percent more efficient than the tankage. In each of the individual experiments, the pigs getting fish meal gained slightly more on the same amount of feed.

In the dry-lot experiments just reviewed neither the fish meal nor the tankage ration was complete. Later investigations have shown both to be deficient especially in a number of the water-soluble vitamins. To compare these two feeds when fed in rations more nearly ideal according to present knowledge, there are given in Table 126 the summarized results of seven experiments conducted by Willman and Morrison of the Cornell Station [23] and two by Robison of the Ohio Station.[24] In the Cornell trials the ration was composed of corn, linseed meal, ground alfalfa (4½ percent of ration), and minerals, and either 60 percent digester tankage or menhaden fish meal. In the Ohio experiments the ration was corn, soybean oil meal, ground alfalfa (4 percent of ration), and minerals and either dry-rendered tankage or fish meal. At both stations the rations were fed according to appetite. The pigs were confined to dry lots under controlled conditions, and fed from a starting weight of 60 pounds to approximately 200 pounds.

The results as averaged are so nearly identical that no other conclusion is possible than that these two supplements are practically of equal value when fed under the conditions represented in these trials.

Menhaden and white fish meal compared. The same investigators, in six trials at the Cornell Station and in two at the Ohio Station, compared these two meals for growing and fattening pigs in the dry lot when fed on rations of the same type as those used in the experiments just reviewed. The pigs fed the menhaden meal in these eight trials

[22] Howard Hackedorn and J. Sotola. Bul. 169, 1922.
[23] John P. Willman and F. B. Morrison, Bul. 730, 1940.
[24] W. L. Robison. Bi-Monthly Bul. 217, 1942.

Table 126. Fish Meal and Tankage Compared for Pigs in the Dry Lot
(Average 9 Experiments)

Rations	*Feed Consumed Daily per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.		lb.
Corn, tankage, linseed or soybean oil meal, ground alfalfa, and minerals	5.74	1.49	Corn	322.1
			Tankage	25.8
			Linseed or soybean o.m.	18.5
			Alfalfa	16.0
			Minerals	3.0
			Total	385.4
Corn, fish meal, linseed or soybean oil meal, ground alfalfa, and minerals	5.89	1.53	Corn	321.3
			Fish meal	23.6
			Linseed or soybean o.m.	17.6
			Alfalfa	19.6
			Minerals	2.9
			Total	385.0

made an average daily gain of 1.48 pounds; those which received the white fish meal gained 1.41 pounds daily. The amount of feed required to produce 100 pounds of gain was practically identical, 378 and 377 pounds, respectively. In both the Ohio experiments somewhat better results were obtained with the menhaden meal. The Cornell workers reported that in two of their six trials the white fish meal gave unsatisfactory results.

Fish meal and tankage compared for pigs on forage. In Table 127 there are summarized the results of 13 experiments in each of which menhaden fish meal and tankage were compared for growing and fattening pigs full-fed on forage. Five of the trials were conducted at the Cornell Station,[25] three at the Ohio Station,[26] and five at the South Carolina Station.[27] At Cornell the ration fed was shelled corn, linseed meal, minerals, and either tankage or fish meal, with oats and rape pasture. The ration fed in the Ohio trials was corn, minerals, and either dry-rendered tankage or fish meal, with rape forage in one and

[25] John P. Willman and F. B. Morrison, Bul. 730, 1940.
[26] W. L. Robison, Bi-Monthly Bul. 217, 1942.
[27] E. D. Kyzer, T. M. Clyburn, R. L. Jones, and E. G. Godbey, Cir. 65, 1940

a combination of alfalfa and clover forage in the other two. At South Carolina the ration fed was white corn, minerals, and either fish meal or tankage, with green rye forage. The pigs were started in the different experiments at weights of 50 to 67 pounds, and in all trials were fed to a market weight of about 200 pounds.

Table 127. Fish Meal versus Tankage for Pigs on Pasture
(Average 13 Experiments)

Rations	*Feed Consumed Daily per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*
	lb.	lb.	lb.
Corn, tankage, and minerals	4.89	1.377	355
Corn, fish meal, and minerals	5.08	1.477	344

Without an exception in any of the trials, the ration containing the fish meal was consumed in slightly larger amounts, and produced faster and more economical gains. The actual average cost of 100 pounds of gain as reported was $5.45 for the tankage ration, and $5.28 for the ration containing the fish meal.

Fish meal and buttermilk compared. Vestal of the Indiana Station [28] compared fish meal and buttermilk as supplements to corn for growing and fattening pigs in the dry lot in two experiments. The corn and fish meal were self-fed, free-choice, while the buttermilk was hand-fed twice daily. The corn in the buttermilk ration was self-fed. In each trial the pigs which had the buttermilk gained about 10 percent faster than those fed the fish meal. The gains of the pigs receiving fish meal were efficiently made, however, for in producing a unit increase in weight 19.5 pounds of the fish meal plus 22 pounds of corn were equal in value to 444 pounds of buttermilk.

Fish meal compared with soybean oil meal. Hostetler of the North Carolina Station [29] found that fish meal gave better results as a supplement to corn for growing and fattening pigs in the dry lot than soybean oil meal in three experiments. In each trial shelled corn was fed in one compartment of the feeder, either fish meal or soybean oil meal in a second, and a mineral mixture in a third compartment. The fish meal (menhaden) averaged 40 percent of protein and the soybean oil meal 39.7 percent. Although practically the same in protein content, the soybean oil meal was consumed in much larger amounts than the fish meal, much more, in fact, than was necessary

[28] C. M. Vestal, Mimeo. Rpt. H-9, 1925.
[29] Earle H. Hostetler, Bul. 259, 1928.

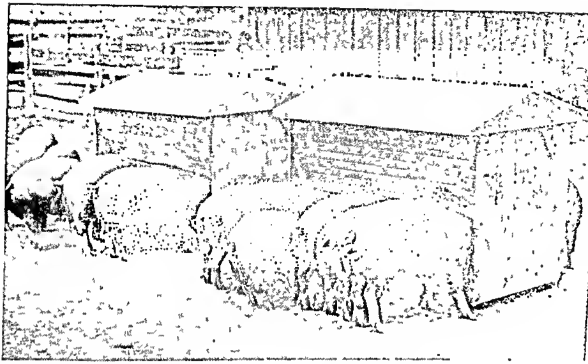


Fig. 54. The self-feeder has become an institution on practically every commercial hog farm in America. Self-fed pigs eat more and gain faster than hand-fed pigs. The feeds, including the minerals, may be ground and mixed and fed all in one compartment of the feeder; or the grain may be fed in one compartment, the protein supplement in a second, and the minerals in a third compartment, in which case the pigs are self-fed, free-choice.

to balance the protein supply. The pigs on the fish-meal ration gained 1.93 pounds daily, as against 1.78 pounds daily for those getting soybean oil meal. Less total feed was required for a unit of gain also on the former ration.

At the same station Foster and Hostetler[30] compared menhaden fish meal with soybean oil meal in three experiments for pigs fed in the dry lot from a weight of about 106 pounds to market weight. Up until the time they went on experiment, the pigs were on good pasture. The rations were shelled corn, minerals, and either fish meal or soybean oil meal, self-fed, free-choice. The pigs which received fish meal gained 1.93 pounds daily and made 100 pounds of gain on 368 pounds of feed. Those fed soybeans made an average daily gain of 1.78 pounds, requiring 397 pounds of feed to produce 100 pounds of gain. The money cost of producing 100 pounds of gain was $6.07 and $7.09, respectively. This difference, however, was in large measure the result of the excessive consumption of the soybean oil meal.

Results secured in four trials by the same investigators[31] [illegible]

[30] J. E. Foster and Earle H. Hostetler, [illegible]
[31] *Ibid.*

that replacing half the fish meal with an equal amount of soybean oil meal produces as rapid and efficient gains as fish meal alone. The combination of the two proved very palatable, with the result that its consumption, when self-fed, greatly exceeded the amount necessary to balance the corn, hence increasing unnecessarily the money cost of the gains. Also, it was found in three trials that self-feeding a supplement made up of equal parts of fish meal, soybean oil meal, and cottonseed meal produced faster and cheaper gains when fed as a supplement to corn to partly grown pigs in the dry lot than fish meal alone.

Studies in other countries. Results secured in three sets of experiments involving eight trials, conducted at the Harper Adams Agricultural College, England,[32] indicated that the protein contained in extracted soya-bean meal (soybean oil meal) was as efficient in balancing a cereal grain ration as the protein contained in white fish meal when fed under carefully controlled dry-lot conditions. Results of extensive studies by German investigators as reported by Crowther,[33] in which the basal ration was composed mainly of barley meal and potatoes, were favorable to the fish meal when compared with soybean oil meal with small additions of chalk ($CaCO_3$) and salt. In trials comparing the common types of fish meal, they found no significant differences.

Hilton of the Dominion Experimental Farm, Nappan, N.S.,[34] reported after extensive studies that, as a protein supplement for growing and finishing bacon pigs, *fish meal gave very satisfactory results* when compared with skim milk and tankage.

Fish meal and peanut oil meal compared. In a series of four experiments at the North Carolina Station [35] fish meal and peanut oil meal were compared when fed to 83-pound pigs in the dry lot for a period of about 80 days. The supplements were self-fed, free-choice, with shelled corn and minerals self-fed. The pigs which received the fish meal gained 1.62 pounds daily and required 395 pounds of feed to produce 100 pounds of gain, at a cost of $6.62. Those fed the peanut oil meal gained 1.32 pounds daily and required 425 pounds of feed for each 100 pounds of gain which cost $7.13. Because of its palatability, 1 pound of peanut oil meal was consumed for each 2.8

[32] T. B. Wood, J. B. Orr, and C. Crowther, *Jr. Ministry of Agr.*, Eng., Vol. 35, 1928.
[33] C. Crowther, *Nut. Abst. and Review*, Imp. Bu. of An. Nut., Rowett Inst., Vol. IV, No. 2, 1934.
[34] S. A. Hilton, *Sci. Agr.*, Vol. XIX, No. 3, 1938.
[35] *Ibid.*

pounds of corn, an amount greatly in excess of that necessary to supplement the ration efficiently or economically.

Does fish meal taint the flesh of pork? German investigations concerning the effect of fish meal on the quality of pork products generally have given negative results.[36] They report that all groups of pigs fed herring meal, with and without varying amounts of skim milk, as a supplement to cereal meal and ensiled potatoes, showed the flesh and fat of the carcasses to be free from fishy or oily taste or odors. Liverwurst prepared from the livers was also of satisfactory quality.

Vestal and associates of the Indiana Station [37] raised four lots of pigs from a weight of 67 to 218 pounds with rations containing different amounts of menhaden fish meal and fish oil to determine their influence on the flavor of the pork. The fish meal contained 5 percent of oil. The results as judged by nine families showed that the control ration containing 10 percent of fish meal did not produce fish-flavored pork. When 0.5 or 1.5 percent of fish oil was added to the basal ration, however, considerable fishiness in flavor resulted, more pronounced in the roasts and bacon than in the chops. Earlier studies by other investigators showed that fish meal when fed in an amount sufficient to balance a corn ration did not produce off-flavored pork.

Marshall and Davis of the Florida Station [38] report that shark meal fed in an amount representing 5.9 to 13.98 percent of the ration did not produce any off- or fishy flavor in the lean or fat of the pork products.

OTHER MARINE PRODUCTS

Shark meal. This protein-rich supplement represents the cooked, dried, and ground portion of the shark carcass which remains after the removal of the hide, liver, dorsal fins, and in some cases the teeth and jaws.

Marshall and Davis of the Florida Station [39] tested the value of this product by comparing it with roller-process powdered skim milk for growing and fattening pigs by the paired-feeding plan. The shark meal used contained an average of 78 percent protein. The basal

[36] *Exp. Sta. Record*, Vol. 79, 1938.
[37] C. M. Vestal, C. L. Shrewsbury, Ruth Jordan, and Opal Milligan, *Jr. An. Sci.*, Vol. 4, No. 1, 1945.
[38] Sidney P. Marshall and Geo. K. Davis, *Jr. An. Sci.*, Vol. 5, No. 2, 1946.
[39] Sidney P. Marshall and Geo. K. Davis, *Jr. An. Sci.*, Vol. 5, No. 2, 1946.

portion of the ration consisted of ground yellow corn, corn starch, and 4 percent of a complex mineral mixture. The shark meal and powdered skim milk were added in such quantities as to supply the protein needs at a minimum level, namely, 17 percent of protein from the start to a weight of 75 pounds, 15 percent from 76 to 100 pounds, 13.5 percent from 101 to 150 pounds, and 12 percent from 151 to the end of the experiment. They were fed by hand, and the feed intake equalized for the pigs of each pair. All pigs received in addition a liberal supply of vitamin A and the better known water-soluble vitamins. The pigs throughout the experiment were kept on concrete, under strictly controlled and sanitary conditions.

The pigs fed the shark meal during the 98-day feeding period made an average gain of 1.5 pounds daily; those which received the skim milk powder gained 1.44 pounds daily. Since the feed consumed of the contrasting rations was the same, it would appear that the protein contained in shark meal is as efficient as that contained in powdered skim milk.

Shrimp meal and tankage compared. Another superior protein supplement of marine origin is shrimp meal or shrimp bran. It is composed mainly of the heads and hull of the shrimp, after having been artificially dried and finely ground. It analyzed 45 to 50 percent of protein, and with an ash content running as high as 30 percent.

Bray and associates of the Louisiana Station [40] made a comprehensive study of this product in three experiments for growing and fattening pigs fed in the dry lot. In Table 128 is presented the summary of their studies in which shrimp meal was compared with standard tankage, fed either as the sole protein supplement, or as the principal supplement along with other supplements of plant origin. In one year cottonseed meal was the additional supplement used, and in another a mixture of cottonseed meal, ground soybeans, and alfalfa meal. The carbohydrate portion of the ration was either corn alone or a combination of corn and rice polish. These components of the ration were fed in the self-feeder, free-choice style. In two of the experiments a good mineral mixture was fed to both lots. The pigs were confined to dry lots, averaged 67 pounds when the experiments began, and were fed over periods lasting from 40 to 70 days.

Without exception the pigs which received the shrimp meal outgained those fed tankage, apparently the result of greater palatability and larger feed consumption. In all cases the shrimp meal was eaten

[40] Chas. I. Bray, J. B. Francioni, Jr., E. M. Gregory, and M. G. Snell. Bul. 228, 1932.

Table 128. Shrimp Meal Compared with Tankage for Pigs in Dry Lot
(Average 3 Experiments)

	Rations	Daily Gain	Feed Required for 1 Cwt. Gain	Cost of 1 Cwt. Gain
		lb.	lb.	
As the only supplement	Shrimp meal	1.53	385	$7.49
	Tankage	1.34	395	$8.22
With other supplements	Shrimp meal	1.68	350	$6.85
	Tankage	1.45	363	$7.34

in larger quantities than the tankage, but owing to its lower protein content more was needed to balance the ration. That the proteins contained in the shrimp meal are of good or superior quality is suggested by the amount of feed required to produce a given gain in weight.

Some type rations balanced mainly with meat or fish supplements.

A. *For fall-farrowed pigs during the winter:*
   1. Corn or other grain, self-fed, + tankage or meat scraps or fish meal, self-fed, + fine-quality legume hay, self-fed.
   2. Ground corn or other cereal 74 to 80 percent, tankage or fish meal 8 to 5 percent, soybean oil meal 8 to 5 percent, and alfalfa meal 10 percent, mixed and self-fed, + simple mineral mixture, self-fed.

B. *For full-fed pigs on good forage:*
   Corn or other grain, self-fed, + a mixture of tankage or meat scraps or fish meal 25 percent, soybean oil meal or linseed meal or cottonseed meal 25 percent, and finely ground oats 50 percent, + flake salt, self-fed.

C. *For pregnant sows and gilts during the last half of the winter gestation period:*
   1. Corn, ground barley, oats, and/or wheat hand-fed in an amount to maintain the right improving condition (about 1¼ pounds daily per hundredweight for mature sow, and 1¾ pounds daily per hundredweight of young sows) + one-third pound daily per sow of tankage or meat scraps or fish meal + fine-quality alfalfa hay or alfalfa leaf meal, self-fed, + a simple mineral mixture, self-fed.
   2. A mixture by weight of ⅓ ground corn or wheat, ⅓ finely ground oats or barley, ⅓ (or more) prime alfalfa meal, and

5 percent of tankage or meat scraps or fish meal, self-fed, + simple mineral mixture, self-fed.

3. A mixture of equal parts, by weight, of finely ground oats and corn 80 percent, alfalfa meal 15 percent, and tankage or fish meal 5 percent, hand-fed according to condition of sows, + simple mineral mixture, self-fed.

D. *For sows nursing pigs:*

1. After sows are on full feed, self-feed a mixture of ground grain 90 percent and tankage or meat scraps or fish meal 10 percent, + green forage pasture + simple mineral mixture, self-fed.
2. For dry lot, after sows are on full feed, hand-feed according to appetite and condition of sows a mixture of ground grain 60 to 65 percent, wheat middlings 20 percent, alfalfa meal 5 to 10 percent, and tankage or meat scraps or fish meal 10 percent, + simple mineral mixture, self-fed.

KITCHEN GARBAGE

Several million tons of kitchen waste of considerable potential feeding value are produced in this country annually. A survey made by the U.S. Food Administration showed that of 66 cities with populations in excess of 100,000 in 1916, more than 30 percent reported that their garbage was disposed of by feeding it to hogs, and of 544 cities with populations between 10,000 and 100,000, more than 36 percent so reported.[41] It was estimated at that time that this product, if handled and fed under ideal conditions, was sufficient to produce 80,000,000 pounds of pork. In 1930 Conti of the Los Angeles County Livestock Department [42] reported the results of a study of methods of disposal used in 64 of the larger cities of the country, the data from which are shown in Table 129.

Table 129. Methods of Municipal Garbage Disposal

Method	*Number All*	*Number Part*	*Percentage All*
Incineration	14	18	21.87
Reduction	6	6	9.37
Hog feeding	37	25	57.81
Fills and dumps	7	13	10.93

[41] F. G. Ashbrook and A. Wilson, U.S.D.A., Farmers' Bul. 1133, 1920.
[42] L. F. Conti, "A Survey of Municipal Garbage Disposal." Reported in An. Rpt. of the Los Angeles Co. L.S. Dept., 1930, L. M. Hurt, director.

According to this survey more than one-half the cities were depending on hog feeding as the sole method of disposal, while more than 95 percent of them used this method solely or in part. Twenty-two percent of the cities depended exclusively on incineration, burning, and less than 10 percent used the reduction system only. In the latter method, the garbage is tanked, part of the grease and fat removed, and the residue dried and ground to produce "processed" garbage, which is sold as a pig feed.

Three surveys made by Inspector Hurt of the Los Angeles County Livestock Department [43] showed the following costs per ton for the different methods of collection and disposal in 90 large cities of the country:

	1930	*1939*	*1949*
Hog feeding	$1.89	$2.29	$4.16
Reduction	5.47	2.82	9.75
Incineration	4.48	3.63	6.59

Feeding value of raw garbage. The amount of pork which can be made from a ton of garbage varies widely, being influenced mainly by the general methods of management employed and the sanitary conditions under which it is fed, and secondly, on the quality of the garbage collected. Hotel, restaurant, and institutional garbage, and that from army and navy stations, is considerably superior in feeding value to household garbage. Much depends, too, on the general prosperity plane. When times are good, the garbage is good; when they are bad, the garbage is not so good.

Municipal garbage, on the dry-matter basis, analyzes about as follows: protein, 15 to 25 percent; carbohydrates, 40 to 50 percent; fats, 20 to 25 percent; and ash, 10 to 15 percent. It contains about 70 percent of moisture. The nutrients are well balanced; the proportion of protein to carbohydrate equivalent (nutritive ratio) is about 1 to 5, and its mineral or ash content is high.

ments of any kind. The raw, uncooked product also is preferred to the treated because the hogs can pick and choose and thus more easily separate the food from the refuse and balance their ration. From the results of experimental studies of the practice of supplementing garbage with grain, made at the Michigan, New Jersey, Mississippi, Kentucky, and Iowa Stations, Ashbrook and Wilson [44] calculated that 516 pounds of garbage was worth 100 pounds of grain. This is probably a much higher feeding value for garbage than is generally realized.

The best method of feeding is to spread the day's collection on fence-enclosed rat-proof cement feeding platforms. Two of these should be provided so that they may be alternated and the refuse promptly removed. The combustible portion is burned and the bones sold. Sometimes the refuse minus the bones is used as a fertilizer in the raw state. Good results are possible only when the garbage is collected regularly and strict sanitary precautions observed. Even with the best of management, the losses will be heavier than occur under general farm conditions.

Quality of pork produced by garbage hogs. Although garbage-fed hogs produce pork of good quality, studies of 600 carcasses by Hughes and Ittner of the California Station [45] indicated that only 37 percent of the pigs fed grain with garbage produced carcasses which graded hard, while for those without garbage 84 percent of the carcasses graded hard. This was the result, no doubt, of the high fat content of average garbage. Garbage-fed hogs, because of their paunchiness, shrink more in shipping and usually dress out two to three points lower than other hogs when killed.

Trichinae in pork. Zeller and Ellis of the U.S. Department of Agriculture [46] report that studies in the Zoological Division of the Bureau of Animal Industry show that the occurrence of trichinae in hogs fed raw garbage is eight times as great as it is in hogs fed cooked garbage. The federal meat inspection service, however, sees to it that all lean pork which is customarily eaten without cooking, such as bologna, frankfurt, Vienna-style sausages, dry summer sausage, cooked ham, Italian smoked ham, is specially treated to destroy all possible live trichinae. This safeguard is accomplished by one of the three following methods: "(1) Heating all parts to a temperature not lower than

[44] F. G. Ashbrook, and A. Wilson, U.S.D.A., Farmers' Bul. 1133, 1920.
[45] E. H. Hughes, and N. R. Ittner, *Food Research*, Vol. 5, No. 1, 1940.
[46] J. H. Zeller, and N. R. Ellis, *Year Book of Agriculture*, 1939.

137°F; (2) freezing all parts to a temperature not higher than 5 F for not less than 20 days; or (3) curing the meat or article according to one of four methods."[47]

PROCESSED GARBAGE

When the reduction method of garbage disposal is employed, the garbage material, minus crockery, glass, and such matter, is tanked to remove most of the fat and the residue artificially dried and finely ground. This product has been designated *processed garbage* by the American Feed Control Officials. To pass inspection it must contain less than 1 percent of glass, none of which is in the form of knife or needle-like particles, and the odor must not be suggestive of decomposition. The maximum percentage of glass should be stated on the label when present in excess of one-fifth of 1 percent. The product runs high in fiber and fat, with an amount of protein about equal to that in wheat middlings. Samples used in the experiments referred to below had the following average composition: protein, 17.4 percent; fat, 25.8 percent; fiber, 19.3 percent; and ash or mineral matter, 13.3 percent.

Processed garbage and tankage compared. Vestal of the Indiana Station[48] conducted four experiments in each of which he compared processed garbage with Number 1 tankage when fed with corn to growing and fattening pigs on forage. The results are averaged and shown in Table 130. In each trial the ground corn and supplement were combined in regulated proportions and self-fed. The proportion of tankage to corn was 1 to 12, and of the processed garbage 1 to 12 or 1 to 8. The pigs weighed 64 pounds at the start of the experiments, and close to market weights at the finish. Alfalfa was the forage in two of the trials, and red clover in two.

Table 130. Processed Garbage Compared with Tankage, on Forage *(Average 4 Experiments)*

Rations	*Daily Feed Consumption*		*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.		lb.	lb.	
Ground corn + tankage	Corn	5.65	1.678	Corn	337
	Tankage	0.47		Tankage	28
	Total	6.12		Total	365
Ground corn + processed garbage	Corn	5.34	1.470	Corn	363
	Proc. garbage	0.56		Proc. garbage	38
	Total	5.90		Total	401

with tankage, in four experiments, under the same conditions as the experiments just reviewed. That this feed lacks much in palatability is indicated by the fact that the pigs ate only 1 part of the processed garbage to 29 parts of corn, while in the comparable lot the pigs ate the richer tankage in the ratio of 1 to 15 parts of corn. Although they needed to consume more than three times as much garbage as tankage to obtain the same protein supply, actually they ate about one-half as much.

Processed garbage with stick. In addition to straight processed garbage the Indianapolis Board of Sanitary Commissioners manufactured an improved product, called "processed garbage with stick." This has a slightly higher protein content than the straight product used in the experiments just reviewed. More recently, by a process of removing more thoroughly the fat, "degreased processed garbage with stick" has been produced. This product has given very fair results in the limited experimental study which has been made of it at the Indiana Station. One sample contained 5.3 percent of moisture, 21.6 percent of protein, 5.4 percent of fat, 29.0 percent of nitrogen free-extract (starches and sugars), 23.3 percent of crude fiber, and 15.4 percent of ash.

Sewage sludge as a pig feed. Bohstedt and Grummer of the Wisconsin Station [51] studied the possible feeding value of activated sludge produced by a Milwaukee sewage disposal plant. This product is high in nitrogen and minerals, and is very rich in the B-complex vitamins. When fed to growing pigs in amounts to represent 6 to 18 percent of

[51] G. Bohstedt and Robt. Grummer, Bul. 466, 1945 and Bul. 469, 1946.

the ration it had definite toxic effects, resulting in the death of several pigs when fed at the higher levels. When fed at levels of 1 to 4 percent, no pronounced effects were observable. In all cases it slowed down the rate of gain and increased the cost of production.

Experimental tests with activated sludge (dried sewage) at the Michigan Station [52] showed that the product was extremely unpalatable. Efforts to get pigs to eat it were reported as unsuccessful. Evidently the conservation of this valuable product is more promising when used as a fertilizer rather than as a feed.

[52] Spl. Bul. 348, Mar. 1948.

XIV *Protein Supplements of Plant Origin*

In this chapter the commercial feeds of plant origin will be considered. These will include the wheat by-products, such as shorts, middlings and bran, linseed meal, soybean oil meal, cottonseed meal, gluten meal and feed, peanut meal and feed.

WHEAT FLOUR MILL BY-PRODUCTS

For each bushel of wheat manufactured into flour, there are produced on the average about 17 pounds of by-products, most of which is standard middlings or shorts, and bran. As shown in Fig. 51, the annual production of these two feeds exceeds in tonnage, on the dry matter basis, that of any other manufactured product. With the exception possibly of the milk by-products and tankage, they are also more exclusively used for swine feeding than any of the other feeds listed.

By-products produced. The typical flour mill by-products, in addition to standard middlings and bran, are flour middlings, red dog, and screenings. The percentage which these represent of the total offal varies considerably among the different mills and is affected too by the type and quality of the wheat ground. The by-products from one mill, not including the screenings, may run 60 percent of bran and 40 percent of middlings or grey shorts; another reports that the mill-feed is divided into 40 percent bran, 40 percent standard middlings, and 20 percent flour middlings; a third produces usually 40 percent bran, 50 percent standard middlings, and 10 percent red dog. Many mills do not produce red dog as such. Always a certain percentage of the bran is reduced and classified as middlings or shorts.

Definitions. The numerous by-products which result from the manufacture of wheat flour are defined by the Association of American Feed Control Officials (1950) as follows:

WHEAT BRAN is the coarse outer covering of the wheat kernel as

separated from cleaned and scoured wheat in the usual process of commercial milling.

WHEAT STANDARD MIDDLINGS consists of fine particles of wheat bran, wheat germ, wheat flour and some of the offal from the "tail of the mill." This product shall be obtained in the usual process of commercial milling and shall contain not more than 9.5 percent of crude fibre.

WHEAT BROWN SHORTS consists of fine particles of wheat bran, wheat germ, wheat flour, and some of the offal from the "tail of the mill." This product shall be obtained in the usual process of commercial milling and shall contain not more than 7.5 percent of crude fibre.

WHEAT GRAY SHORTS, WHEAT GRAY MIDDLINGS, OF WHEAT FLOUR MIDDLINGS consists of fine particles of wheat bran, wheat germ, wheat flour, and the offal from the "tail of the mill." The product shall be obtained in the usual process of commercial milling and shall contain not more than 6 percent of crude fibre.

WHEAT RED DOG, WHEAT WHITE SHORTS, OF WHEAT WHITE MIDDLINGS consists of the offal from the "tail of the mill," together with some fine particles of wheat bran, wheat germ, and wheat flour. This product shall be obtained in the usual process of commercial milling and shall contain not more than 4.0 percent of crude fibre.

WHEAT FEED FLOUR consists principally of wheat flour together with fine particles of wheat bran, wheat germ, and the offal from the "tail of the mill." This product shall be obtained in the usual process of commercial milling and shall contain not more than 1.5 percent of crude fibre.

shorts or middlings which it is necessary to feed in order to balance the cereal grains is consequently much greater than when these richer protein feeds are fed. They occupy a position intermediate between the carbonaceous grains, on the one hand, and the richer nitrogenous or protein supplements, on the other. As a matter of fact, they function as substitutes for, as well as supplements to, the cereal grains. Their extensive use in pork production throughout the country is evidence of their economy and usefulness. Judging from the fact that the proteins of wheat are not of the best quality and, much like corn, we should conclude that the wheat by-products would not be especially efficient in balancing qualitatively the protein deficiencies of corn.

The mineral characteristics of these products are such that special attention should be given them by the feeder. Like the cereal grains they are very low in calcium or lime and relatively high in phosphorus. This low calcium content is a fault common to all the plant supplements, but in none of those generally used in pig feeding is it so serious as in shorts, bran, and middlings.

Table 131. Composition of Wheat By-products[1]

	Dry Matter	*Protein*	*N-free Extract*	*Fiber*	*Fat*	*Calcium*	*Phosphorus*
	%	%	%	%	%	%	%
Bran, all analysis	90.1	16.9	52.9	9.6	4.6	0.14	1.29
Standard middlings, all analysis	89.6	18.1	55.8	6.5	4.8	0.09	0.93
Red dog	89.2	17.9	57.9	4.9	4.8	0.07	0.51
Flour middlings	89.2	18.3	59.8	3.8	4.2	0.09	0.71
Wheat mixed feed	89.7	17.2	56.1	7.2	4.5	0.11	1.09
Wheat screenings	90.4	13.9	58.2	9.0	4.7	0.44	0.39
Wheat germ meal	90.8	31.1	42.2	2.6	9.7	0.08	1.11
Wheat germ oil meal	89.1	30.4	46.4	2.6	4.9	...	...
Wheat grain, all types	89.5	13.2	69.9	2.6	1.9	0.04	0.39

There is little, if any, vitamin A or D in the flour-mill by-products, a characteristic common to practically all commercial protein supplements. Also, those essential vitamins belonging to the B-complex group, including B12, are found in very meager amounts. Vitamin E,

[1] F. B. Morrison, *Feeds and Feeding*, 21st ed., Tables I, Appendix, Morrison Publishing Co., Ithaca, N. Y. 1948.

known as the antisterility vitamin, is present in high concentration in the oil of the wheat germ. It is possible that the finer grades of middlings and red dog, therefore, have special value in helping to maintain regular breeding habits in the herd.

Compared with the cereal grains and most of the common protein supplements, bran is high in its fiber content, analyzing from 9 to 12 percent. Screenings and mill-run, or wheat mixed feeds, will often run as high as 8 percent of fiber. This, along with their high swelling property on soaking, is the principal reason why bran and these latter feeds are not suitable in large amounts for young pigs. Because of these same properties, however, they are valued in the maintenance rations for the breeding classes.

Standard middlings, flour middlings, and red dog compared. During the summers of 1923 and 1924 Ferrin and McCarty of the Minnesota Station [2] performed the interesting experiment of comparing the different flour-mill by-products when fed with corn and tankage to pigs on alfalfa. The basal ration fed was corn, tankage, and minerals, to which was added either standard middlings, flour middlings, or red dog flour in the respective lots. One lot received the basal ration only. The other lots received from 65 to 75 percent of corn, 23 to 30 percent of one of the mill-feeds and 2 to 5 percent of tankage, the proportion of the mill-feeds and tankage being reduced after the pigs had reached the weight of 100 pounds. The wheat by-products replaced approximately one-third of the corn and one-half the tankage. The shelled corn was fed dry in a trough, and the mill-feed and tankage mixed together and hand-fed in the form of a thin slop. Each experimental group of 10 pigs had access to one-half acre of alfalfa forage. The trials began on July 10, the pigs averaging 66 and 71 pounds in the two experiments, and closed on November 3 and 5 when the pigs in each lot averaged approximately 200 pounds. The results, which were remarkably uniform in the two trials, are averaged and shown in Table 132.

The authors concluded from these two experiments that it will pay to use wheat by-products along with corn and tankage, to the extent of representing at least one-third of the ration, for pigs on good forage, with the prices current at the time the experiments were run. Based on the results of the 1924 trial, they determined that the feeder could afford to pay for a ton of standard middlings 31 times the price of a bushel of corn; for a ton of flour middlings he could pay 36 times the

[2] E. F. Ferrin and M. A. McCarty. Mimeo. H-15, 1924.

Table 132. Wheat By-products Compared When Fed with Tankage to Pigs on Alfalfa Pasture
(Average 2 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
Shelled corn + tankage + minerals	4.20	1.085	Corn	361
			Tankage	26
			Total	387
Shelled corn + tankage + standard middlings + minerals	4.35	1.110	Corn	295
			Tankage	16
			St. mids.	86
			Total	397
Shelled corn + tankage + flour middlings + minerals	4.44	1.160	Corn	284
			Tankage	16
			Flour mids.	83
			Total	383
Shelled corn + tankage + red dog flour + minerals	4.32	1.115	Corn	286
			Tankage	16
			Red dog	85
			Total	387

price of a bushel of corn; and for a ton of red dog flour he could afford to pay 40 times the price of a bushel of corn. These figures are useful also in indicating the relative values of the three wheat products when fed under these conditions.

Because of the large tonnage produced annually and their extensive use by hogmen, it is apparent that middlings have a logical place in swine rations generally. This place is secured for it by its cheapness, its ability to substitute in part for the carbonaceous grains and the more expensive protein supplements, its superior palatability when fresh, and its mild laxative qualities. It is highly regarded as a base in making up slops for breeding stock, particularly when fitting for show. For its most efficient use, however, it should be fed with other protein supplements, largely animal or fish in origin, and in rations otherwise supplied with adequate minerals and vitamins.

Palmo midds. In the manufacture of tin plate, wheat middlings, or a mixture of middlings and ground wheat screenings, are used as an absorbent to remove the palm oil from the tin plate. The resulting product is sold as *palmo midds.* It is practically the same in composi-

tion as middlings except that its fat content is more than twice as great.

Early experiments at the Indiana Station[3] showed that self-feeding a mixture of three parts palmo midds and one part tankage with corn, self-fed, gave as good results for fattening partly grown pigs in the dry lot as a mixture of three parts middlings and one part tankage. On neither ration, however, were the gains as rapid or economical as on a third ration balanced with tankage alone. Robison of the Ohio Station[4] compared palmo midds and flour wheat middlings when fed as the only carbonaceous feeds, each balanced with tankage, to pigs averaging about 80 pounds at the start in the dry lot. Although the pigs fed the palmo midds ate slightly more feed, they gained 14.2 percent less rapidly than those fed the flour middlings and required 20.3 percent more feed for a unit of gain. Fed in this manner, the palmo midds had a calculated value of 77 percent of that of the flour middlings.

Some typical rations containing wheat products. Below are given some balanced feed combinations in which middlings or shorts represent a considerable part of the ration. They are recommended for those areas where feed prices are favorable to their use.

A. *For fall pigs during the winter:*
   1. Shelled corn, self-fed, + a slop made of 4 to 5 parts middlings and 1 part tankage or meat scraps or fish meal, hand-fed in an amount, dry basis, about equal to one-half the amount of corn consumed + fine-quality alfalfa hay in rack + a mineral mixture composed of equal parts ground limestone, special bone meal, and common or iodized salt, self-fed.
   2. A mixture composed of 30 percent finely ground oats, 30 percent ground barley, 25 percent shorts or middlings, 5 percent fish meal, and 10 percent of alfalfa meal, by weight, + a simple mineral mixture, self-fed.

B. *For spring pigs full-fed on forage:*
   1. A mixture of 6 parts ground oats or barley, 3 parts shorts or middlings, and 1 part meat scraps or fish meal, self-fed, + a simple mineral mixture, self-fed.
   2. Shelled corn, self-fed, + a mixture of 5 parts middlings and 1 part tankage or meat scraps or fish meal, self-fed, + a simple mineral mixture, self-fed.

[3] J. H. Skinner and C. G. Starr, Bul. 219, 1918.
[4] W. L. Robison, Bul. 607, 1939.

C. *For creep-feeding nursing pigs:*

Shelled corn, self-fed, + a thick slop made with skim milk or buttermilk and flour middlings or red dog, hand-fed according to appetite twice daily, + a simple mineral mixture composed of 35 percent finely ground limestone, 35 percent special steamed bone meal, 28 percent salt, and 2 percent copperas (ferrous sulphate crystals, finely ground), self-fed.

D. *For pregnant sows during the winter:*

1. A mixture composed of 70 to 75 percent ground oats or other grain, 20 percent middlings or shorts, 0 to 5 percent tankage or fish meal, and 5 percent alfalfa leaf meal, by weight, hand-fed according to weight and condition of the sows, + a simple mineral mixture, self-fed.
2. A mixture of 60 to 65 percent ground grain, 30 percent shorts or middlings, 5 percent linseed or soybean oil meal, and 0 to 5 percent meat scraps or fish meal, hand-fed according to condition of sows, + fine-quality alfalfa hay fed in rack + a simple mineral mixture, self-fed.

Substitute bran for the middlings in the above rations just before and after farrowing.

E. *For nursing sows after they are on full feed:*

1. Ten to 15 ears of corn daily + a fairly thick slop of middlings and skim milk or buttermilk, hand-fed twice daily according to appetite, + a simple mineral mixture, self-fed, + green forage.
2. A mixture of 30 percent finely ground oats, 30 percent ground barley, 30 percent shorts or middlings, 5 percent meat scraps or fish meal, and 5 percent high-grade alfalfa meal, self-fed, + simple mineral mixture, self-fed.

F. *For the boar before and during the breeding season:*

1. A mixture composed of 45 percent ground grain, 40 percent shorts or middlings, 10 percent bran, and 5 percent tankage or meat scraps, hand-fed, dry or as a slop, according to condition, + green feed + a simple mineral mixture, self-fed.

SOYBEAN OIL MEAL

Of the 181,362,000 bushels of soybeans produced in the United States in 1947, less than 2 percent was fed to livestock. Most of the remainder was crushed for oil, the production of which increased by more than 400 percent from 1937 to 1947.[5] It is interesting to observe

[5] *Agr. Statistics,* U.S.D.A., 1948.

here that approximately 80 percent of this oil was used as food, chiefly in lard substitutes (46 percent) and in the manufacture of margarine (16 percent).[6] This indicates the production of an enormous tonnage of soybean oil meal, as well as the relative unimportance of the harvested soybeans themselves as feed.

Methods of manufacture. Three different methods of oil extraction have been employed by soybean processors, namely, the old hydraulic, the expeller, and the newer solvent method.

In the *hydraulic* method the oils are removed by cooking and the application of hydraulic pressure. The beans are first run through grinding rolls and then thoroughly cooked in large steam-jacketed cookers at a regulated temperature well above the boiling point of water for a period of about an hour and a half. The cooked meats are then placed in the hydraulic press, after which the residue cake is cracked or ground. This method is reported now to be practically abandoned.[7]

In the *expeller process* of oil extraction, the beans are cracked and then dried to a moisture content of about 2 percent. The material is then "tempered" by being subjected to a temperature of 212 to 240°F for a period of 10 to 15 minutes in an apparatus equipped with an agitator to ensure uniform heating, after which it is fed into the expeller. Here the oil is expressed by pressure exerted in the horizontal steel barrel by a centrally revolving worm shaft. The frictional heat generated in the process is subject to some control by the operator through varying the pressure within the unit, and varies normally from 220 to 280°F during the 2 to 2½ minutes required for the material to pass through the expeller. The soybean cake or residue leaves the expeller in the form of small chips, which are then generally ground before marketing.[8] Since the last war there has been a decided trend toward converting from the expeller to the solvent method of extraction.[9]

In the *new solvent process* method the beans are cracked, preheated to a temperature of 140°F for 10 minutes, run through grinding rolls, following which they are subjected to the dissolving action of a solvent, such as hexane. The residue is then passed through tubular driers during which it is subjected to a definitely regulated temperature

[6] *The Soybean Blue Book*, American Soybean Assn., 194[illegible].

[7] Egbert Freyer, Spencer-Kellogg and Sons, Inc., Buffalo, N. Y. [illegible] the author, 1950.

[8] J. W. Hayward, Archer-Daniels-Midland Co., Bul. 7, 19[illegible].

[9] Egbert Freyer, Spencer-Kellogg and Sons, Inc., Buffalo, N. Y. [illegible] the author, 1950.

for a period of about 15 minutes, sufficient to cook it thoroughly. The material leaves the drier in the form of flakes, which are then generally ground into meal. It is estimated that 70 percent of the soybeans are now processed by the solvent and 30 percent by the expeller method.[10]

Processing temperatures important. Relatively high processing temperatures are necessary in the production of the various types of soybean oil meal if the protein content is to function efficiently in nutrition. Hayward and associates of the Wisconsin Station [11] showed that commercial soybean oil meals which had been prepared at medium to high temperatures, such as expeller meals processed at temperatures from 233 to 302°F for 2½ minutes, or hydraulic meals cooked at 221 to 250°F for 90 minutes, contained proteins which had about twice the nutritive value of the protein contained in raw soybeans or meals processed at low temperatures. In the production of solvent extracted oil meal it was found that heating to a temperature of 208°F for 15 minutes was effective in improving the efficiency or biological value of the protein.

In metabolism and growth experiments, these investigators, using rats, determined that processing at high temperatures resulted in an increase of 3 percent in digestibility and an improvement in the biological value of the protein amounting to 12 percent. They suggested the possibility that the heating caused the availability of some essential protein factor, which is unavailable for absorption in raw soybeans or in the meals processed at low temperatures. That this concerns the amino-acid cystine was shown in later studies in which it was demonstrated that the addition of 0.3 percent of L-cystine to raw soybeans resulted in giving to the protein a value equal to that of the protein of meals processed at high temperatures.

In practical feeding tests with growing and fattening pigs in the dry lot, it was shown at the Wisconsin [12] and Ohio Stations [13] that the soybean oil meals which were processed at medium to high temperatures generally were superior in palatability and more efficient in producing gains than those produced when relatively low temperatures were used. The experiments by Carroll of the Illinois Station,[14] however, indicated that expeller meal processed at a temperature of 120°F was as palatable as that which was processed at a temperature

[10] Wilfred M. Witz, Archer-Daniels-Midland Co., Information to the author, 1950.
[11] J. W. Hayward, H. Steinbach, and G. Bohstedt, *Jr. of Nut.*, Vols. 11 and 12, 1936.
[12] J. W. Hayward, G. Bohstedt, and J. M. Fargo, *Proc. Am. Soc. An. Prod.*, 1934.
[13] W. L. Robison, Bul. 452, 1932.
[14] W. E. Carroll, Ills. Exp. Sta., An. Rpt., 1932–33.

of 310°F. His results also showed expeller meal to be much superior in palatability to hydraulic meal, regardless of the temperatures employed.

At the present time sufficiently high temperatures are used in all three methods of oil extraction to ensure palatability and maximum value of protein quality in the meal. From the experiments that have been made in which the meals produced by the three methods of oil extraction have been compared, it probably is safe to conclude that they are practically of equal value as now produced.

Definitions. The Association of American Feed Control officials [15] define the soybean products as follows:

SOYBEAN OIL MEAL is the ground soybean oil cake or chips. A name description of the process of manufacture, such as expeller, hydraulic, or solvent extracted, shall be used as part of the brand name. It shall be designated and sold according to its protein content.

EXPELLER SOYBEAN OIL CHIPS is the product obtained after expressing part of the oil from soybeans by crushing, cooking and mechanical pressure using an expeller, screw press, or any other mechanical press. It must be designated and sold according to its protein content.

EXPELLER SOYBEAN OIL MEAL is the product resulting from grinding expeller soybean oil chips.

SOLVENT-EXTRACTED SOYBEAN FLAKES is the product obtained after extracting part of the oil from soybeans by the use of solvents.

SOLVENT-EXTRACTED SOYBEAN OIL MEAL is the product resulting from grinding solvent extracted soybean flakes.

HYDRAULIC SOYBEAN OIL CAKE is the product obtained after expressing part of the oil from soybeans by crushing, cooking, and hydraulic pressure.

HYDRAULIC SOYBEAN OIL MEAL is the product resulting from grinding hydraulic soybean oil cake.

Composition of oil meals. The average composition of the different types of soybean oil meal, together with that of cottonseed and linseed meal, is shown in Table 133.

In protein content the soybean oil meals rank slightly higher than cottonseed meals, and very much higher than linseed meals. As with all protein feeds of plant origin, they all are seriously deficient in minerals, especially calcium and common salt. Although not high in phosphorus, they contain more than twice as much of this element as

[15] Ind. Exp. Sta., Cir. 351, 1949.

Table 133, Composition of Oil Meals [16]

Feed	*Dry Matter*	*Protein*	*N-free Extract*	*Fiber*	*Fat*	*Calcium*	*Phosphorus*
	%	%	%	%	%	%	%
Soybean oil meal, expeller or hydraulic, all analysis	90.9	44.3	29.6	5.7	5.3	0.29	0.66
Soybean oil meal, solvent process	90.6	46.1	31.8	5.9	1.0	0.30	0.66
Soybean seed	90.0	37.9	24.5	5.0	18.0	0.25	0.59
Linseed meal, old process, all analysis	91.0	35.4	36.0	8.2	5.8	0.39	0.87
Linseed meal, solvent process, all analysis	90.4	36.9	36.3	8.7	2.9	...	...
Flaxseed	93.8	24.0	24.0	6.3	35.9	0.26	0.55
Cottonseed meal, 43% protein	92.7	43.9	26.3	9.0	7.1	0.23	1.12
Cottonseed meal, solvent process	90.8	44.4	24.3	12.7	2.6	...	...
Cottonseed kernel	93.6	38.4	15.1	2.3	33.3	...	...
Peanut oil meal, old process, all analysis	93.0	43.5	23.4	13.3	7.6	0.16	0.54
Peanut oil meal, solvent process	91.6	51.5	27.2	5.7	1.4	...	...
Peanut kernel	94.6	30.4	11.7	2.5	47.7	0.06	0.44
Peanut oil feed, unhulled	93.1	35.0	21.4	22.5	9.2	...	...
Corn germ meal	93.0	19.8	53.2	8.9	7.8	0.03	0.34
Corn oil meal, old process	91.7	22.3	49.0	10.3	7.8	0.06	0.56

of calcium. They also are deficient in those growth-stimulating vitamins, which are essential for health and production efficiency, namely, A, D, and those belonging to the B-complex and related groups.

Another characteristic of some significance possessed by all the oil meals is their large swelling capacity when soaked in water. The swelling factor (the soaked and centrifuged volume times the dry volume) for linseed meal is 3.76, for expeller soybean oil meal 2.57, and for cottonseed meal 2.41 (see page 184).

Solvent-extracted soybean oil meal, because of the more complete extraction of the oil, contains considerably less fat and more protein than the meals produced either by the expeller or hydraulic process.

[16] F. B. Morrison, *Feeds and Feeding*, 21st ed., Table I, Appendix, 1948. The Morrison Publishing Co., Ithaca, N. Y.

A slightly greater supplemental value, therefore, should be expected of it.

Soybean oil meal and tankage compared. Without exception, experiments comparing these two protein supplements for growing and fattening pigs in the dry lot have given results which favor the tankage. The summarized results of 12 trials made by Robison of the Ohio Station,[17] shown in Table 134, are representative of such studies. In these trials 55-pound pigs were fed in dry lots to weights approximately of 200 pounds. The rations were so constructed that approximately the same amount of protein and minerals was fed in both rations.

Table 134. Soybean Oil Meal versus Tankage for Growing and Fattening Pigs in the Dry Lot
(Average 12 Experiments)

Rations	*Initial Weight per Pig*	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*
	lb.	lb.	lb.	lb.
Corn + tankage + minerals	55	4.57	1.13	406
Corn + soybean oil meal + minerals	55	4.37	1.07	409

The tankage ration proved more palatable and produced somewhat faster gains. Neither ration, however, is complete. Both are deficient in vitamin D, and those belonging to the B-complex group, and the soybean ration is lacking in addition the important animal protein factor or factors (APF). For younger pigs especially, a ration of yellow corn, soybean oil meal, and minerals is inadequate, resulting in loss of appetite, a declining rate of gain, and the development of skin afflictions toward the end of the feeding period (see page 228).

When soybean oil meal and tankage are compared for pigs on good forage, with minerals added to the soybean rations, the experiments show them to be practically equal in efficiency, as was shown in Table 54.

Some type rations containing soybean oil meal. Below are given a few examples of satisfactory rations for the different classes of hogs in which soybean oil meal is believed to be most efficiently employed.

A. *For fall pigs during the winter:*

[17] W. L. Robison, Bi-Monthly Bul. 223, 1943.

1. Corn or other grains, self-fed, + a mixture by weight of soybean oil meal 25 percent, tankage or meat scraps or fish meal 25 percent, and alfalfa meal 50 percent, self-fed, + a simple mineral mixture, self-fed.
2. Ground corn or other grains 74 to 80 percent, soybean oil meal 8 to 5 percent, tankage or meat scraps or fish meal 8 to 5 percent, and alfalfa meal 10 percent, mixed and self-fed, + a simple mineral mixture, self-fed.

B. *For full-fed pigs on good forage:*

1. Corn or other grains, self-fed, + a mixture of finely ground oats 50 percent and soybean oil meal 50 percent, self-fed, + a simple mineral mixture, self-fed.
2. Ground corn or other grains 88 to 92 percent, soybean oil meal 8 to 6 percent, meat scraps or fish meal 4 to 2 percent, mixed and self-fed.

C. *For pregnant sows and gilts during the last half of winter gestation period:*

1. A mixture by weight of ground corn or wheat 30 percent, finely ground oats or barley 30 percent, and prime alfalfa meal 32 (or more) percent, 6 percent soybean oil meal, and 2 percent of tankage or meat scraps, self-fed, + simple mineral mixture, self-fed.
2. A mixture of ground corn 45 to 50 percent, ground oats 31 percent, alfalfa meal 10 to 15 percent, soybean oil meal 6 percent, and tankage or meat scraps 3 percent, hand-fed, either dry or as a slop, in an amount to maintain the right condition and weight, + simple mineral mixture, self-fed.

D. *For sows nursing pigs:*

1. After sows are on full feed, self-feed a mixture composed of ground grains 88 percent, soybean oil meal 8 percent, and tankage or fish meal 4 percent, + a simple mineral mixture, self-fed, + green forage.
2. For dry lot conditions, after sows are on full feed, hand-feed according to appetite and condition of the sows a mixture of ground grain 70 to 75 percent, wheat middlings 10 percent, alfalfa meal 5 to 10 percent, soybean oil meal 8 percent, and meat scraps 2 percent, + simple mineral mixture, self-fed.

SOYBEANS

Practically all of the immense tonnage of soybeans now harvested in the country is used for its oil; less than 2 percent of the production

is fed. Formerly their use as a home-grown protein supplement in swine rations was fairly general, and many experiments were conducted, comparing them with tankage and other supplements.

Two principal reasons are responsible for the decline in the use of soybeans for feed: the increasing popularity and use of soybean oil in the manufacture of lard substitutes, margarine, and paints give to the beans a market value which is higher than their feed value, and secondly, the high oil content of the beans, averaging about 18 percent, results in the production of soft carcasses when the beans are fed throughout the growing and fattening period.

Raw soybeans, either ground or whole, are not very palatable. Experiments at the Ohio, Indiana, and other stations have shown that cooking or roasting the beans increases markedly their palatability and gain-producing efficiency, especially when fed under dry-lot conditions. Whole soybeans have been shown to be equal or slightly superior to ground soybeans.

Whole soybeans can be fed successfully, however, when, because of price or weather damage, they cannot be marketed profitably. Their most profitable use, probably, is secured when they are cooked or roasted and the amount fed limited to constitute about one-half the protein supplement, part of which should be meat meal, fish meal, or other feeds of animal origin. To make the ration complete, green pasture must be available, or alfalfa meal fed in an amount to equal about 10 percent of the ration by weight. A simple mineral mixture, self-fed, also is required, especially under dry-lot conditions.

LINSEED MEAL

Practically all of the flaxseed grown in the country is used in the manufacture of linseed oil. *Linseed oil meal* or *linseed meal* represents the dried and ground residue which remains of the flaxseed after most of the oil has been extracted. This is a fairly rich protein feed, highly prized as a supplement for all classes of livestock. Its production is about one-fifth of that of soybean oil meal, which—along with its popularity as a cattle and sheep feed—means that it occupies a secondary position as a protein concentrate in pork production.

Definitions. Three methods are employed in the extraction of the oil, as in the case of soybeans, namely, hydraulic (old process), expeller, and solvent, and are defined as follows by the Association of American Feed Control Officials: [13]

[13] The Feed Bag. Red Book. 1950.

HYDRAULIC LINSEED OIL CAKE is the product obtained by expressing part of the oil from flaxseed by crushing, cooking, and hydraulic pressure. It must be designated and sold according to its protein content.

HYDRAULIC LINSEED OIL MEAL is ground hydraulic linseed oil cake.

EXPELLER LINSEED OIL CHIPS is the product obtained by expressing part of the oil from flaxseed by crushing, cooking, and mechanical pressure, using an expeller, screw press, or any other mechanical press. It must be designated and sold according to its protein content.

EXPELLER LINSEED OIL MEAL is the product obtained by grinding expeller linseed oil meal chips.

SOLVENT-EXTRACTED LINSEED OIL FLAKES is the product obtained by extracting part of the oil from flaxseed by using a combination of mechanical pressure and solvents or by the use of solvents alone. It must be designated and sold according to its protein content.

SOLVENT-EXTRACTED LINSEED OIL MEAL is the product obtained by grinding solvent extracted linseed oil flakes.

LINSEED CUBES OR PELLETS consist of linseed oil meal which has been processed through a cubing or pelleting machine. They shall be firm, but not flinty, of sweet odor, free of mold, and, when ground, shall produce linseed oil meal as defined.

Linseed meal, in other words, is the finely ground cake, chips, or flakes obtained in the various methods of oil extraction.

Most of the processors are now using the expeller method in the extraction of the oil from flaxseed. The hydraulic process had practically disappeared by 1942. It is estimated that only a small percentage of the mills have been converted from the expeller to the solvent method although there is a definite trend in that direction.

Composition and feeding qualities of linseed meal. The protein content of linseed meal averages about 36 percent, which is 8 to 10 units less than it is in soybean oil meal or cottonseed meal. Like the other oil meals and protein supplements of plant origin, linseed meal is especially deficient in calcium, common salt, and vitamins, and its protein quality is only of fair value. The quality in linseed meal most highly esteemed by the feeder is its laxativeness, the result probably of the residual oil and the high swelling factor of 3.76. It also is credited with the ability to impart a natural gloss or sheen to the hair coat, a feature of some importance in hogs fed for show.

Linseed meal and tankage compared. There have been numerous experiments in which linseed meal and high-grade tankage have been compared in rations for growing and fattening pigs, both under dry-lot

and forage conditions. In some of these the corn-linseed ration was supplemented with mineral additions to make it similar in this particular to the tankage ration; in others the same mineral mixture was fed in both lots; and in still other cases no minerals were fed in either lot. In some of the comparisons the feeds were self-fed, free-choice while in some they were mixed in definite proportions and then self fed, or hand-fed according to appetite. Most of the trials covered the period from soon after weaning to the time market weights were attained, while in others it included the finishing period only.

A systematic study of the results obtained in these different experiments appears to support the following general observations relative to the efficiency of these two protein supplements.

In practically every instance, regardless of the method of feeding employed or the conditions under which the experiments were run, the pigs receiving tankage gained considerably faster than those getting linseed meal. The difference varied, as a rule, from 10 to 50 percent for the dry-lot experiments and less than this maximum when forage was available. The younger the pigs also, the greater was the difference in rate of gain. This difference was due to the larger consumption of the ration containing the tankage and to a greater variety of food deficiencies in the linseed ration.

Table 135. Linseed Meal versus Soybean Oil Meal for Growing and Fattening Pigs
(Average 3 and 2 Experiments)

Rations	Daily Feed Consumption	Daily Gain	Feed Required 1 Cwt. Gain	
	lb.	lb.	lb.	
Corn + soybean oil meal + minerals—Forage	4.60	1.327	Corn	•312.31
			Soybean oil meal	34.32
			Total	346.63
Corn + linseed meal + minerals—Forage	4.50	1.278	Corn	314.45
			Linseed meal	39.30
			Total	353.75
Corn + soybean oil meal + minerals—Dry lot	4.31	0.966	Corn	400.13
			Soybean oil meal	46.31
			Total	446.44
Corn + linseed meal + minerals—Dry lot	4.59	0.970	Corn	435.30
			Linseed oil meal	38.41
			Total	473.71

oil meal was worth about 20 percent more than the linseed. The number of experiments was too limited and the variation in the results of the dry-lot trials too great, however, to make the result conclusive.

Allowing for the difference in protein content, these two supplements may replace one another in swine rations generally without affecting the results noticeably.

COTTONSEED MEAL

Cottonseed meal represents the dried and ground residue which remains after most of the oil has been removed from the cottonseed kernel. The production of cottonseed cake and meal in the United States in 1948 was 4,799,200 tons, of which 1.7 percent was exported (net export).[21] A relatively small proportion of this supply, however, is fed to hogs. This is caused by its popularity as a protein concentrate for dairy cows and fattening steers, by its extensive use in the West and Southwest to supplement the winter feed supplies for range

[21] Feed Statistics, U.S.D.A., Bu. Agr. Ec., Statistical Bul. 85, 1949.

stock, and finally by the general belief that when fed to hogs there is danger of poisoning.

Composition of cottonseed meal. Chemical analysis of cottonseed meal gives it a composition very similar to that of soybean oil meal Its protein content varies usually from 38 to 45 percent, depending on the grade, which is considered to be only of fair quality. The fat ranges from 2 to 7 percent, and the fiber content from 9 to 12 percent Like the other protein feeds of plant origin, it is very deficient in calcium and common salt. It contains little vitamin A or D activity, limited amounts of the B-complex vitamins, and probably none of those new vitamins which have been associated with the animal protein factor

Methods of cottonseed oil extraction. The hydraulic process, in which the oil is removed in hydraulic presses, is still predominant among cottonseed processors, although the screw-press expeller type has gained in popularity during the past 10 years. The solvent extraction method is a very recent development; only three or four mills are reported as using it at the present time.[22]

Definitions. The principal cottonseed products suitable for swine feeding are described by the *Association of Feed Control Officials* as follows:

to a compound called *gossypol.* When extracted gossypol was fed to pigs, it produced the symptoms characteristic of cottonseed-meal poisoning.

Sewel of the Alabama Station [24] in extensive studies, using rats, chicks, and hogs, showed rather clearly that the toxicity of cottonseed meal was due primarily to the *free gossypol.* He found in analyzing the meals from 16 mills in Alabama, practically all of which were using the hydraulic process, that the free gossypol ranged from 0.055 to 0.255 percent, and the bound gossypol from 0.627 to 1.041 percent. When the meal containing the least amount of free gossypol was fed to hogs at the level of 25 percent of the ration, it proved to be toxic. The meal containing the larger amounts killed 6 of 8 hogs, but was not toxic after the free gossypol had been eliminated.

Cottonseed meal may be fed safely. As the result of much research and many practical experiments, it has been shown how cottonseed meal may be used in swine rations safely.

Hale of the Texas Station,[25] in a comprehensive series of experiments from 1924 to 1928, demonstrated that it could be fed safely to all classes of hogs when certain restrictions as to the amount and conditions were observed. His tests seem to furnish conclusive evidence that as much as 9 percent of cottonseed meal in the ration can be fed to brood sows, boars, and nursing pigs with entirely satisfactory results. As much as 15 percent was fed to several sows through six successive gestation and lactation periods without producing any ill effects. The appetite of the sows was better, however, when the ration was changed to one containing 9 percent of cottonseed meal and 4 percent of tankage. His trials also showed that creep rations, containing 9 percent of cottonseed meal, produced pigs at weaning time equal in weight and appearance to those fed tankage. The meals fed in these experiments were untreated and, presumably, produced by the usual hydraulic process of oil extraction.

Methods that help to render cottonseed meal harmless. Many experiments, particularly those begun by Robison of the Ohio Station [26] in 1928, have shown that the toxic qualities of cottonseed meal could be destroyed or greatly reduced by autoclaving, *i.e.,* by moistening and cooking under 14 pounds of steam pressure for one hour. Robison fed 14 different lots of pigs an average of 13.6 to 21.2 percent of un-

[24] W. E. Sewell, Bul. 259, 1943.
[25] Fred Hale, Bul. 410, 1930.
[26] W. L. Robison, Bul. 534, 1934 and Bi-Monthly Bul. 199, 1939.

treated hydraulic cottonseed meal in the ration to growing and fattening pigs in the dry lot. Fifty-three percent of the pigs died before the tests were terminated. Two other groups of similar pigs were fed hydraulic meal that had been moistened and autoclaved one hour at the level of 18.4 and 21.2 percent of the ration. No deaths occurred in these lots.

In five feeding trials Robison of the Ohio Station [27] compared iron-treated hydraulic meal with untreated meal when fed at a level of about 16 percent of a ration of corn, 4 percent of alfalfa meal, and minerals. The iron treatment consisted of adding 2 pounds of copperas (iron sulphate), in solution, to 100 pounds of the cottonseed meal The 49 pigs fed the iron-treated meal made the average daily gain of 0.93 pound, none showing any evidence of poisoning. Of the 49 pigs fed the untreated meal, 31 succumbed during the feeding period.

Robison describes the symptoms of cottonseed meal poisoning as follows: "Loss of appetite, a general listlessness, an anemic appearance, thumping, or labored breathing, and eventually death." Post-mortem examination showed "large quantities of an amber-colored serous fluid in the peritoneal and plural cavities, and inflammation of the blood vessels of the intestines and mesentary."

Experimental feeding trials. Since from 14 to 16 percent of cottonseed meal alone in the ration would be necessary to supply sufficient protein to balance the grain, it is apparent that the safe procedure to follow when feeding it is to include a second protein concentrate, preferably of animal or marine origin. Hale of Texas recommends a supplement in which cottonseed meal represents 9 percent and tankage 4 percent of the ration, or 9 percent of cottonseed meal and one-half gallon of skim milk daily to each pig. We now know that the inclusion of an animal protein concentrate to such a ration is highly desirable also from the standpoint of the supply of a number of vitamin-like factors.

Foster and Hostetler of the North Carolina Station [30] showed by the results of four dry-lot experiments with pigs weighing about 80 pounds at the start that a mixture of equal parts fish meal and cottonseed meal was superior to fish meal alone when fed as a supplement to a ration of corn and minerals. Experiments generally have also shown that practically as good results may be obtained from rations balanced with tankage and cottonseed meal as from those balanced with tankage and either linseed or soybean oil meal.

Robison of the Ohio Station [31] summarized the results of 20 experiments in which cottonseed meal replaced linseed meal in the Wisconsin or trio-mixture for growing and fattening pigs, both in the dry lot and on pasture. The averaged results were in close agreement, although the pigs receiving the linseed made slightly faster gains in the dry-lot trials.

Rations containing cottonseed meal. The following rations containing cottonseed meal are both efficient and safe for feeding the different classes of hogs.

A. *For fall pigs during the winter:*

1. Corn or other grain, self-fed, + a mixture by weight of cottonseed meal 25 percent, tankage or meat scraps or fish meal 25 percent, and alfalfa meal 50 percent, self-fed, + a simple mineral mixture, self-fed.
2. Ground corn or other grain 74 to 80 percent, cottonseed meal 8 to 5 percent, tankage or meat scraps or fish meal 8 to 5 percent, and alfalfa meal 10 percent, mixed and self-fed, + a simple mineral mixture, self-fed.

[30] J. E. Foster and Earl H. Hostetler, Tech. Bul. 56, 1933.
[31] W. L. Robison, Bul. 534, 1934.

For full-fed pigs on good forage:

1. Corn or other grain, self-fed, + a mixture of two parts cottonseed meal and one part fish meal or meat scraps, by weight, self-fed, + a simple mineral mixture, self-fed.
2. Ground corn or other grain 88 to 92 percent, cottonseed meal 8 to 6 percent, meat scraps or fish meal 4 to 2 percent, mixed and self-fed, + a simple mineral mixture, self-fed.

For pregnant sows and gilts during the last half of the gestation period:

1. A mixture by weight of ground corn or wheat 30 percent, finely ground oats or barley 30 percent, and alfalfa meal 32 (or more) percent, 6 percent of cottonseed meal, and 2 percent of tankage or fish meal, self-fed, + a simple mineral mixture, self-fed.
2. A mixture of ground corn 45 to 50 percent, ground oats or barley or wheat 31 percent, alfalfa meal 10 to 15 percent, cottonseed meal 6 percent, and tankage or meat scraps or fish meal 3 percent, hand-fed, either dry or as a slop, in an amount to maintain the right condition and weight, + a simple mineral mixture, self-fed.

For sows nursing pigs:

1. After sows are on full feed, self-feed a mixture composed of ground grains 88 percent, cottonseed meal 8 percent, and meat scraps or fish meal 4 percent, + a simple mineral mixture, self-fed, + green forage.
2. For dry-lot conditions, after sows are on full feed, hand-feed according to appetite and condition of the sows a mixture of ground grain 70 to 75 percent, wheat middlings 10 percent, cottonseed meal 7 percent, tankage or meat scraps or fish meal 3 percent, and alfalfa meal 5 to 10 percent, + a simple mineral mixture, self-fed.

Government's price-support program, were responsible for price inflation during the postwar period, and a high general price level was the result.

The average monthly farm prices of these grains per hundredweight from 1939 to 1948 inclusive are shown in Fig. 57. The prices received by farmers for all the grains dropped from January to February, following which they tended to advance until the beginning of the harvest season for the respective crops, after which a tendency to decline for

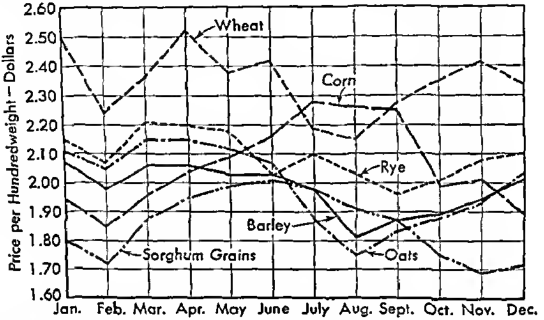


Fig. 57. Average monthly farm prices of the common cereal grains in the United States, 1939 to 1948, inclusive (Feed Statistics, *U.S.D.A., Bu. Agr. Ec., Statistical Bul.* 85, 1949).

a time is apparent. The price of corn varied from month to month more widely than that of any of the other grains. The seasonal or prospective seasonal demand on the available or prospective seasonal supply normally may be expected to determine the price at any given time.

Composition of the cereal grains. The deficiencies of corn and the other cereal grains in meeting the nutritional requirements of the pig have been discussed in some detail in Chapters VII and VIII. Some but not all of these deficiencies are revealed by the usual chemical analysis, as shown in Table 137.

These grains are all characterized by a very high carbohydrate content, a rather low supply of protein, and a marked deficiency of the important mineral element calcium. They also are deficient in most of the other minerals, especially of common salt. The protein quality

whole corn. On the average, the efficiency of the two was practically equal.

It appears from all these experiments that older pigs profit more from grinding than do younger ones. In the early Indiana trials, in which the effect of the age or weight was especially studied, no difference either in the rate or the amount of feed required for a unit of gain was found between whole and ground corn for pigs fed from 78 to 150 pounds; while for pigs fed from 180 to a final weight of 300 pounds somewhat faster and more efficient gains were made on the ground corn.

On the whole, it may be concluded that grinding corn for growing and fattening pigs up to market weight is unnecessary. When facilities are available on the farm, however, and/or when it is desired to feed with it other ground grains, or/and supplements in definite proportions, the cost of grinding may be more than compensated for by the greater ease of mixing and feeding. Especially should this be true for the older breeding classes of hogs.

Fine grinding of corn not advisable. Results obtained at the Wisconsin[12] and Pennsylvania Stations[13] indicate rather clearly that finely ground corn is less suitable for growing and fattening pigs than corn ground medium or coarse. Four comparisons were made at each station, some in the dry lot and some on pasture. The corn was ground in a hammer mill, using $\frac{3}{32}$-, $\frac{3}{16}$-, and $\frac{1}{2}$-inch screens, respectively, for the production of the fine, medium, and coarse.

In six of the eight trials, the pigs which received the medium-ground corn made faster gains and required slightly less feed to produce a unit of gain than either group fed the coarse- or fine-ground corn. On the average, the pigs on the medium-ground corn gained 5.5 percent faster than those on the fine-ground, and 2.6 percent faster than those fed the coarse-ground corn.

The power requirements for fine grinding also are much greater than for medium or coarse grinding. Results of the tests made at the Pennsylvania Station showed that the number of kilowatt-hours required for each 100 pounds of feed was 55 percent greater for producing fine (modulus, 1.99 to 2.22) than for medium (modulus, 2.42 to 2.77), and 55 percent greater for medium than for coarse ground (modulus, 3.06 to 3.25).

[12] G. Bohstedt, B. H. Roche, J. M. Fargo, I. W. Rupel, and F. W. Duffee, *Proc. Am. Soc. of An. Prod.*, 1931.
[13] M. A. McCarty, J. E. Nicholas, and T. B. Keith, Bul. 326, 1936.

Some open-pollinated varieties may be superior to some hybrids, and the reverse probably is true when other varieties are compared. Of the several hybrids and open-pollinated varieties tested in these experiments there is no basis for the claim that either, in general, is superior to the other.

Moisture content and hardness important factors. Robison of the Ohio Station[18] concludes several years' study of the factors influencing the feeding value of corn with the following significant observations:

1. Pigs preferred some corn to others. Of those tried, the less palatable corn, when it was fed separately—that is, when it was the only one available—produced practically as rapid and as efficient gains as the more palatable ones. The preferences were not for open-pollinated as against hybrid corns but apparently were influenced, directly or indirectly, by the moisture content of the corns.
2. Consistently, a higher value was obtained for a hard dent hybrid corn than for one that was not so hard. On an equivalent moisture basis, it showed an average worth of 6.9 percent greater a pound than the standard corn. The average amounts of moisture in the hard and softer corn as fed were 17 and 19 percent, respectively. The advantage of the hard over the softer corn decreased as the feeding period advanced.
3. Flint corn which was still harder produced a trifle less, rather than more, gain per unit of feed than the standard dent hybrid corns. As with the hard hybrids, the relative effectiveness of the flint corn decreased as the pigs became heavier.
4. Drying hard dent hybrid corn to summer dryness, or an average of 10.3 percent of moisture, apparently did not reduce its palatability but lowered its effectiveness or feeding value. Its average worth was 93 percent that of the standard and 88 percent that of the undried hard corn.
5. Immature corn, that was kept from molding by drying, was worth fully as much, per pound of dry matter contained, as was mature corn. The loss from late planted or immature corn, that is kept without spoiling, is in a reduced yield of grain, on a dry matter basis, per acre rather than in a lowered feeding value, per pound of dry matter produced.
6. On an equivalent moisture basis, except when molded, the long-season or late-maturing corn, like the immature corn, showed a feeding value a pound as high as that of standard corn.
7. Freezing did not impair the nutritive value of immature corn.
8. Molded corn was worth 88.7 percent as much a pound, on an equivalent moisture basis, as sound corn. Doubtless, the worth of moldy corn varies with its condition.

General conclusions. The following general observations and conclusions concerning corn appear to be warranted by the experimental studies which have been made.

[18] W. L. Robison, Bimonthly Bul. 225, 1944.

Based on observations made during the progress of the experiments and the final results, the authors concluded as follows: Young pigs masticate whole corn more thoroughly than do older hogs. Young pigs do not relish dry ground corn as do older hogs. Soaking corn is more advantageous for 200-pound hogs on pasture than when in the dry lot. Shelled corn soaked 12 hours is better than that soaked 24 hours. Hogs under 200 pounds in weight made the most economical gains when their corn was fed in the form of dry ear corn, although shelled corn soaked in water 12 hours made slightly faster gains. Hogs over 200 pounds in weight made more economical gains on shelled corn soaked in water 12 hours than on dry ear corn or ground corn in either form, and the gains on soaked shelled corn were nearly as rapid as on any of the other forms in which corn was fed.

Hybrid and open-pollinated corn compared. Experiments at the Indiana,[15] Minnesota,[16] and Ohio Stations [17] suggest that any differences in the feeding value of hybrid and open-pollinated corn are due less to differences between the varieties than to variations which occur within the variety itself, such as in moisture content, hardness, grade, or general soundness. Four trials were run at Indiana, two at Minnesota, and eight at Ohio. In each case a standard variety of open-pollinated corn was compared with two popular types of hybrids. At the two former stations, the rations, including the protein concentrates and mineral mixtures, were self-fed, free-choice; at Ohio the corn and protein supplement were mixed together and self-fed. Excepting in Indiana trials, the pigs were confined to dry lots. The pigs averaged about 50 pounds at the start and in all cases were fed to market weight. The results as averaged are summarized in Table 140.

Table 140. Hybrid versus Open-pollinated Corn for Growing and Fattening Pigs
(Average 14 Experiments)

Rations	*Average Initial Weight*	*Average Daily Gain*	*Average Daily Feed Consumption*	*Concentrates Required per 1 Cwt. Gain*
	lb.	lb.	lb.	lb.
Hybrid corn	50	1.49	5.71	383
Open-pollinated corn	50	1.50	5.68	379

[15] C. M. Vestal, Mimeo. Rpts., 1939 and 1940.
[16] E. F. Ferrin and D. W. Johnson, Mimeo. H-78, 1941.
[17] W. L. Robison, Bimonthly Bul. 228, 1944.

1. Young pigs up to a weight of about 125 pounds do as well on whole corn, fed shelled or on the ear, as on ground corn. For older pigs and the breeding classes, however, grinding is often justified by the slightly faster gains secured and greater convenience in mixing and feeding.

2. Grinding to a medium degree of fineness is preferred either to fine or coarse grinding. Young pigs especially do not take kindly to finely ground meal.

3. There is no advantage for shelled over ear corn except that it may be a more advantageous method of feeding it.

4. Pigs over 100 pounds in weight usually will gain faster on soaked shelled corn than on dry shelled corn, and faster on soaked ground corn than on dry ground corn. This is especially true when they are on forage.

5. On the basis of the trials made, hybrid and open-pollinated corn have been shown to have equal values, on the average.

6. Differences in the value of corn are due chiefly to differences in soundness and moisture content. Hard dent corn is superior to immature corn; on the dry-matter basis, however, immature corn that has been kept free of mold by drying is equal to hard corn.

7. Flint corn is a trifle less efficient than standard-dent hybrid corns.

8. Because of its high fiber content, corn and cob meal (ground ear corn) is too bulky and indigestible to be suitable for pigs. The tough rubbery character of the cob also makes fine grinding difficult and costly.

9. Normally, when pigs are changed from a diet of soaked or ground corn to one of dry shelled or ear corn they experience a temporary check in gains.

OATS

The tonnage of oats produced in the United States from 1943 to 1947, inclusive, was approximately one-fourth that of corn. This crop is a fixture in many Corn Belt rotations and is extensively grown in the small grain-growing areas of the North and Northwest. Although the horse and mule population has continued to decline, the farm price of 100 pounds of oats from 1939 to 1948, inclusive, was 96 percent of 100 pounds of corn (see Figs. 56 and 57). For the months of July, August, and September, however, when normally corn prices are highest of the year and oat prices lowest, corn averaged during this period

oats as corn were consumed. That it is the hull of the oat grain, which pigs object to, was shown by the fact that twice as much hulled oats as corn were eaten in Lot IV.

Oats and corn compared for growing and fattening pigs. Oats alone cannot be fed to growing and fattening pigs with the expectation of maximum gains even when *adequately supplemented. This is especially* true when the pigs are young. Numerous experiments as well as everyday observations testify to this fact. They may be very successfully used, however, if they are ground and mixed in certain limited proportions with other, less bulky grains.

Rather extensive experimental studies have been made by the various stations, particularly at Illinois,[20] Indiana,[21] and Ohio,[22] concerning the value of oats when substituted for corn in whole or part in well-balanced rations for market pigs. In Table 142 are given the estimated or computed values of oats in terms of corn which seem to harmonize most closely with all the results which have been obtained in well-controlled experiments. In all cases these trials were conducted under dry-lot conditions with growing and fattening pigs fed to approximate market weight, the rations being balanced with tankage or the trio-mixture of two parts tankage, one part linseed meal, and one part alfalfa meal, and usually a mineral mixture in addition. In practically all cases the oats were ground medium or fine. The corn was generally ground or cracked and mixed with the ground

Table 142. Computed Values of Ground Oats in Terms of Corn when Replacing Corn in Rations for Growing and Fattening Pigs in Dry Lot

oats and the mixture self-fed. The rations were fed dry in all the experiments.

From these results it would appear that good quality oats may be used successfully to replace a third of the corn without affecting the gains made by the pigs. In fact, when only one-fifth to one-fourth as much oats as corn are fed the gains are likely to be a little faster than on the corn ration. When the ration is more than one-third oats, however, the rate of gain tends to decrease as the proportion of oats increases. When the corn is wholly replaced by oats, the pigs normally may be expected to gain only from 65 to 75 percent as rapidly as those on corn alone and supplement. Much depends, however, on the quality of the oats.

Since replacing corn with oats results in a reduction or saving in the amount of the protein supplement consumed, the computed value of oats in terms of corn is modified considerably when different values are placed on a pound of the supplement.

The above experiments were all conducted under dry-lot conditions. When pigs are on forage there is reason to believe that the value of oats would be no more, probably less, than when fed in the dry lot, because the bulky character of the forage leaves little space in the stomach of the pig for the accommodation of other bulky feeds. In three trials by Robison of the Ohio Station [23] in which a ration of 3½ parts corn and one part oats with supplement was compared with corn and supplement for pigs on forage, the oats had a computed value of 67.7 percent of that of the corn.

Oats for brood sows. For feeding pregnant brood sows during the winter or summer, or the development of young breeding stock, oats have a larger place and a much higher value than when used for full-feeding market pigs. They can very appropriately constitute a larger proportion of the grain ration. If they are of good weight and cheap in price they may be fed as the sole grain. As a rule, for sows nursing pigs and young gilts and boars on forage, no more than one-half oats in the grain mixture will give the best results.

Oats should be ground. In Table 143 are summarized the results of eleven dry-lot experiments, each of which was undertaken for the purpose of determining if it paid to grind oats for growing and fattening market pigs. Eight of the experiments were made at the Illinois Station [24] and three at the Indiana Station.[25] Only those oat rations were

[23] W. L. Robison, Bul. 607, 1939.
[24] W. E. Carroll, Cir. 414, 1933 and Bul. 436, 1937.
[25] C. M. Vestal, Mimeo. Rpts., 1928.

considered in which the amount of oats fed was limited to the proportions known to give satisfactory results, ranging from two parts corn to one of oats to four parts corn to one of oats. In most of the experiments the ratio was 3 to 1. The oats used weighed from 27 to 32 pounds to the bushel. The oats were ground medium or fine in nearly all cases; in two the grind was coarse. The corn and oats were mixed together and either self-fed or hand-fed according to appetite. The corn was cracked in the Illinois experiments and fed shelled in the Indiana trials. In all cases the rations were fed dry. The supplement was either tankage or the trio-mixture.

Table 143. Whole versus Ground Oats for Growing and Fattening Pigs
(Average 11 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
Corn + whole oats + supplement	5.57	1.144	Corn	305
			Whole oats	131
			Supplement	51
			Total	487
Corn + ground oats + supplement	5.53	1.237	Corn	274
			Ground oats	125
			Supplement	48
			Total	447

The rate of gain on the ration containing the ground oats was on the average 8 percent faster than on the comparable ration in which the oats were fed whole. In none of the Illinois experiments, however, was there any significant difference in the rate of gain.

With respect to the saving of feed effected by grinding the oats, the results indicate a rather decided advantage in favor of grinding. In no single trial did the grinding fail to reduce the amount of feed required to produce a unit of gain. On the average, 100 pounds of ground oats had a value equal to 105 pounds of whole oats, 24.8 pounds of corn, and 2.4 pounds of supplement. Converting the corn and supplement to terms of oats, by using relative average prices as the basis, 100 pounds of ground oats were worth 133 pounds of the whole oats; or the whole oats were worth only 75 percent as much as the ground oats. This difference is more than double the usual cost of grinding. The fact that pigs waste more oats when they are fed whole than ground is probably the principal reason for the difference in value. Ground

oats also are probably a little more completely digested and have a somewhat higher net energy value.

Ordinarily oats should be ground fine or medium fine. Although finely ground oats are more palatable and are eaten with less waste, the experiments at the Illinois and Indiana Stations do not show a significant difference in favor of fine as compared with medium grinding when fed with corn and a supplement to pigs in the dry lot. Crampton and Bell of McGill University,[26] however, found that pigs of 50 pounds initial weight individually fed coarse, medium, and fine ground oats, adequately supplemented with proteins and minerals, made significantly faster gains as the modulus became finer. At the end of the 60-day feeding period the average weights of the pigs receiving the coarse, medium, and fine oats were 121, 132, and 155 pounds, respectively. They also found that the fibrous hulls were decidedly unpalatable and, unless finely ground, were sorted out and refused.

Carroll reports that the power cost of grinding oats fine (3/32-inch screen in hammer mill) is about double that required for coarse grinding (5/16-inch screen). Vestal's studies showed the total grinding costs, including fixed charges and labor, to be as follows: coarse (1/4-inch screen), 8 cents per 100 pounds; medium (1/8-inch screen) 19 cents; fine (1/16-inch screen), 48 cents; and for grinding hulled oats (3/16-inch screen), 7 cents per 100 pounds. These costs were based on prices current 20 years ago. Present costs would be 75 to 100 percent greater.

Free-choice feeding of whole oats. When whole oats are fed free-choice style along with corn and a protein supplement, that is, in a separate compartment of a self-feeder, the quantity of oats eaten compared with corn is always small. Much will depend of course on the quality of the oats. In a trial at the Illinois Station[27] 1 part only of oats was consumed for each 5 parts of corn; in two experiments at the Iowa Station[28] the amount of whole oats eaten was less than 1 part to 15 parts of corn. When ground instead of whole oats are fed in this way, the oats will be eaten in somewhat larger amounts; and the finer the oats are ground, the larger will be the proportion consumed.

Hulled oats a concentrated feed. Since most of the fiber of oats is contained in the hull, the kernel or groat is much more digestible and consequently higher in feeding value than the whole oats. Hulled oats

[26] E. W. Crampton and J. M. Bell, Jr. An. Sci., Vol. [illegible], No. 2, May, [illegible].
[27] J. B. Rice and L. J. [illegible], Mimeo. Rpt.
[28] Evvard, et al., Leaflet 139 and Mimeo. [illegible]

In all but one of the experiments the pigs which received the ration containing the hulled oats gained faster than those in the comparable lot which received no oats. In the other trial the gains were the same. This difference was due chiefly to the greater palatability and larger consumption of the ration containing the hulled oats. Part of it was probably due also to the fact that the latter was slightly more concentrated in character and hence more digestible.

The ration containing the hulled oats also proved to be somewhat more efficient, for 16 pounds of feed were saved in the production of each 100 pounds of gain. One hundred pounds of hulled oats had the average value in these experiments of 96 pounds of corn and 19.6 pounds of supplement, or the equivalent approximately of 131 pounds of corn.

Although 100 pounds of hulled oats as fed in these experiments had a value equal to 131 pounds of corn, it does not follow that hulled oats are an economical feed to use in feeding pigs for market. There are required 150 to 165 pounds of whole oats to produce 100 pounds of hulled oats, and the cost of hulling will average 15 to 25 cents per hundredweight of the whole oats processed, or about 32 cents for each 100 pounds of hulled oats.

Hulled oats compared with ground oats. In the oat-feeding work at the Illinois Station, referred to above, there were four trials in which hulled and ground oats were compared when each was fed in limited proportions with corn and a suitable supplement. The proportion of corn to oats in the different trials varied from two to four of corn to one of the oats. Those fed the hulled oats gained a little faster and with a saving of 26 pounds of feed in the proportion of 100 pounds of gain. One hundred pounds of the hulled oats had a calculated value of about 140 pounds of the ground oats. But since 150 to 165 pounds of whole oats are required to yield 100 pounds of hulled oats, and since the cost of hulling usually exceeds the cost of grinding, it would appear that hulling oats is too expensive a process to be considered practical in commercial feeding.

Hulled oats may have a place, however, in rations for sucking pigs and in fitting hogs for show. For creep-feeding, Ferrin[illegible] suggests self-feeding hulled oats and shelled corn, free-choice, with a slop feed containing skim milk or buttermilk in addition. Hulled oats are popular with many fitters of show hogs, especially when maximum gains are essential to the necessary finish.

[illegible] E. F. Ferrin, Pamphlet No. 21, 1931

are a concentrated feed. They contain more digestible nutrients than corn and are considerably richer than corn in protein; the oat kernel is about 16 percent protein, while corn is about 10 percent. When oats are run through a huller, the kernels recovered amount to 60 to 65 percent of the weight of the original oats, nearly 40 percent being represented by hulls.[29] "Steel-cut" oats, which are available on the market, are hulled oats. Varieties of hull-less oats have been developed, but thus far none have yielded sufficiently well to be considered promising.

In Table 144 there are brought together and averaged the results of eight experiments, in each of which a ration of corn, hulled oats, and a supplement was compared with corn and a supplement for growing and fattening pigs from an average initial weight of 65 pounds to a final weight of about 200, in the dry lot. The proportion of hulled oats to corn in the individual experiments varied from two to four parts corn to one of hulled oats, the average being two and a half. The supplement fed consisted of the trio-mixture of tankage, linseed, or soybean oil meal, and alfalfa meal. In one of the experiments "steel-cut" oats were fed, and in one hull-less oats. In all cases the corn and hulled oats were mixed by hand and self-fed. The supplement was fed in a separate compartment of the feeder. The corn was either cracked or ground. Seven of the trials were run at the Illinois Station [30] and one at the Ohio Station.[31]

Table 144. Corn and Hulled Oats Compared with Corn for Growing and Fattening Pigs

(Average 8 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
Corn + supplement	5.52	1.281	Corn	366
			Supplement	65
			Total	431
Corn + oat kernels + supplement	5.68	1.370	Corn	268
			Oat kernels	102
			Supplement	45
			Total	415

[29] W. E. Carroll, Ills. Exp. Sta., Cir. 414, 1933.
[30] W. E. Carroll, R. S. Smith, G. E. Hunt, and W. P. Garrigus, Mimeo. Rpts., 1926, 1927, 1929–1930, and A. H. 161–175, 1932–1933.
[31] W. L. Robison, Cir. 10, 1928.

In all but one of the experiments the pigs which received the ration containing the hulled oats gained faster than those in the comparable lot which received no oats. In the other trial the gains were the same. This difference was due chiefly to the greater palatability and larger consumption of the ration containing the hulled oats. Part of it was probably due also to the fact that the latter was slightly more concentrated in character and hence more digestible.

The ration containing the hulled oats also proved to be somewhat more efficient, for 16 pounds of feed were saved in the production of each 100 pounds of gain. One hundred pounds of hulled oats had the average value in these experiments of 96 pounds of corn and 19.6 pounds of supplement, or the equivalent approximately of 131 pounds of corn.

Although 100 pounds of hulled oats as fed in these experiments had a value equal to 131 pounds of corn, it does not follow that hulled oats are an economical feed to use in feeding pigs for market. There are required 150 to 165 pounds of whole oats to produce 100 pounds of hulled oats, and the cost of hulling will average 15 to 25 cents per hundredweight of the whole oats processed, or about 32 cents for each 100 pounds of hulled oats.

Soaking or wetting oats. When ground oats are fed by hand somewhat less will be wasted if fed wet in a slop rather than dry. The limited studies that have been made, however, do not indicate that wetting or soaking ground or whole oats increases their feeding value.

Fermenting oats with yeast. There are two kinds of yeast, live yeast and dead yeast. *Live or Active Dry Yeast,* as tentatively defined by the Association of American Feed Control Officials, is yeast that has been dried in such a manner as to preserve a large proportion of its fermenting power. It must contain no added cereal or filler and must contain not less than 15 billion live yeast cells per gram. This is bakers' yeast.

Dead yeast is represented by brewers' dried yeast, which is officially defined as follows: *Brewers' Dried Yeast* is the dried, non-fermentive, non-extracted yeast resulting as a by-product from the brewing of beer and ale and shall contain not less than 40 percent of crude protein on the moisture-free basis. Any claim concerning the value of this type of yeast as a supplement in swine rations must depend on its rather rich supply of the B-complex vitamins and its protein content.

Irradiated yeast is yeast that has been subjected to the ultraviolet rays of artificially produced sunlight in order to increase its antirachitic properties. It is available in potencies of 4, 8, 12, 16, and 24 million U.S.P. units of vitamin D per pound.[33] It is an economical and extremely potent source of vitamin D2 for pigs.

Yeast culture feeds. Claims by the manufacturers of yeast culture feeds that fermenting soaked oats from one feed to the next renders the oat hulls more digestible has been shown by numerous feeding tests to be without foundation. These products normally contain in addition to live yeast a large variety of minerals and salts. Any value they may have is far exceeded by their cost. There is no logical basis for the assumption that fermenting oats will improve their quality or feeding value. The enzymes contained in yeast are not capable of changing in any way the crude fiber of the ration; their action is concerned with the fermentation of sugar with the production of alcohols and acids, products of lower food value than the sugars. Carroll of the Illinois Station,[34] following his studies of the effects of yeast fermentation on the feeding value of oats, stated: "The only conclusion is that oats treated with these preparations are no more valuable for swine than the same oats before treatment."

[33] *The Feed Bag Red Book,* 1950.
[34] W. E. Carroll, Cir. 414, 1933.

Results obtained by Robison of the Ohio Station,[35] however, suggest that yeast may have a place in swine rations as a cheap source of the B-complex vitamins. He tested the value of a homemade yeast culture made by adding a 3-cent cake of yeast with water to a portion of the ration and allowing it to grow for a period of 24 hours, when added to a ration of ground yellow corn, soybean oil meal, ground alfalfa (4 percent of ration), and minerals. Some of this wet mash was then added as a "starter" to the wetted ration that was to be fed 24 hours later. In winter it was necessary to keep the wetted feed in a heated room in order for the yeast to grow. Aside from the extra labor involved, he said that adding water to the feed and growing yeast was an inexpensive procedure. The actual expenditure did not exceed 15 cents for a group of 12 to 15 pigs.

In six experiments he compared this wet ration containing the growing yeast with the same ration without the yeast fed dry to growing and fattening pigs in the dry lot. He summarized the results of this study as follows: "The pigs on the wet feed containing the growing yeast grew normally and remained healthier than those on the dry feed without yeast. Thirteen out of 82 on the dry feed, and three out of 82 on the wet feed containing the growing yeast were removed during the course of the experiments because of unthriftiness. Those on the wet feed containing the growing yeast made faster gains and greater gains per unit of feed than those on the dry feed. In each of the five later trials (dry ration, self-fed) the pigs on the wet feed containing the growing yeast made more rapid gains and were ready for market 16 days earlier, on the average, than those on the dry ration without the yeast. They also required an average of 8.9 percent less feed per unit of gain."

vived, and these died 5 and 9 days later. The treated oats proved very unpalatable. Symptoms of poisoning were a weak, unsteady gait, scouring and vomiting, dizziness, turning in circles, blindness, paralysis, and death. The authors concluded that hogs should not be forced to eat treated seed oats.

Emmer; spelt. Emmer is grown principally in South and North Dakota, Nebraska, Minnesota, and Colorado. It is very much like oats in composition. The hull constitutes from 20 to 30 percent of the grain, the fiber content running nearly as high as that of oats. It is therefore not adapted to growing or fattening pigs when full gains are sought, except when combined in limited proportions with other and more concentrated grains. Experiments indicate that satisfactory results may be expected when the emmer is ground and fed with corn in the proportion of about one part emmer to three of corn, provided the ration is balanced with protein and mineral supplements along with fine-quality legume hay or green forage to supply the necessary vitamins. Feeding equal parts of corn and emmer does not give satisfactory results in full feeding because the ration is too bulky. The rules for the successful feeding of oats to pigs and breeding stock may be appropriately followed in the use of emmer.

Spelt is very similar to emmer in composition and physical characteristics. Like emmer, the hull is not removed from the kernel in threshing. Results of three trials conducted by Freeman of the Michigan Station,[37] in which a combination of ground corn and ground spelt was compared with a similar combination of ground corn and ground oats for pigs fed in the dry lot from an initial weight of 50 to approximately 190 pounds, indicate that spelt and oats are about equal in value. In each trial one lot received the grain mixture in the ratio of one of corn to one of spelt or oats, and in the other the ratio was 75 percent corn and 25 percent spelt or oats. The grains were adequately supplemented with a protein mixture containing tankage, soybean oil meal, and alfalfa meal, and a simple mineral mixture.

The pigs fed the spelt outgained those fed oats, on the average, by the difference between 1.295 and 1.170 pounds daily; but 4.67 percent less of the oats ration was required to produce a unit of gain.

[37] V. A. Freeman, Qt. Bul., Vol. 24, No. 1, 1941.

WHEAT

Production and price of wheat. During the decade 1940 to 1949 the tonnage of wheat produced in the United States was 38 percent of the tonnage of corn. But wheat is a bread crop, and only 10 to 15 percent of it normally is available as feed. The price of wheat compared with corn consequently is so high that its use for feeding is not general. However, following years of short corn crops, wheat prices are frequently low enough compared with corn to make its use as feed economical. Also, it is to be noted from Fig. 57 that new wheat in July and August is generally lower in price than old corn. This would be particularly true in the wheat-growing areas outside the Corn Belt.

Like the other cereal grains, wheat is a carbonaceous feed, deficient in protein, minerals, and vitamins. Although not so exclusively fattening in its properties as corn, nor so lacking in calcium, it cannot be fed alone to any of the classes of hogs with good results. Like corn, wheat is very concentrated in character and palatable.

Wheat compared with corn. In Table 145 are given the averaged results obtained when ground wheat was compared with corn in well-balanced rations for growing and fattening pigs. These experiments were conducted at the Ohio, Missouri, Minnesota, Indiana, Nebraska, Maryland, Colorado, Kansas, and Michigan Stations. Ten of the comparisons were under dry-lot conditions and four under forage conditions. In all but five of the trials the corn was fed whole. The grain and supplement were fed free-choice style in a self-feeder in 12 of the experiments, while in four the two were mixed and fed by hand in a slop according to appetite. The average weight of the pigs was 76 pounds when the experiments began, and market weight when they closed.

In general, the pigs getting the wheat ration did a little better than those fed the corn ration. In six of the trials the gains were more rapid on wheat and in five more rapid on the corn ration; in the other three they were practically the same. When the supplements and grain were fed free-choice style, that is, in separate compartments of a self-feeder, the amount of the supplement consumed by the pigs on the wheat ration was considerably less than by those on the corn ration. This was due to the greater palatability of the wheat and also to the fact that less supplement was needed to balance it, since wheat is richer than corn in protein.

Table 145. Shelled or Ground Corn versus Ground Wheat for Growing-Fattening Pigs

(Average 10 and 4 Experiments)

Rations	*Daily Gain*	*Daily Feed Consumption*	*Feed Required for 1 Cwt. Gain*		*Comparative Values*
	lb.	lb.	lb.		
Corn + supplement (dry lot)	1.329	5.36	Corn	354	
			Sup.	49	100
			Total	403	
Ground wheat + supplement (dry lot)	1.337	5.31	G. Wheat	361	
			Sup.	36	107
			Total	397	
Corn + supplement + forage	1.630	6.00	Corn	344	
			Sup.	24	100
			Total	368	
Ground wheat + supplement + forage	1.677	6.45	G. Wheat	371	
			Sup.	14	99
			Total	385	

In general, the pigs fed the wheat rations did a little better than those getting the corn rations. In six of the trials the gains were more rapid on the wheat, and in four more rapid on the corn rations; in the other four trials they were practically the same. When the grain and supplements were fed free-choice style, that is, in separate compartments of the self-feeder, the amount of the supplement consumed by the pigs which received wheat was considerably less than by those on the corn ration. This was due chiefly to the fact that wheat is richer than corn in protein, and hence less was needed to balance the ration.

In the Purdue experiments on forage, included here, the pigs on the wheat ration tended slightly to grow more and fatten less than those receiving corn, although the wheat-fed pigs were satisfactorily finished. The carcasses of the wheat-fed pigs were found to be somewhat firmer when graded at the packing house. The earlier experiments at Missouri indicated also a slightly superior quality in the carcasses of wheat-fed compared with corn-fed pigs.

Wheat usually should be ground. The experimental data given in Table 146 represent a summary of 11 experiments conducted at the Oklahoma, Maryland, Kansas, Nebraska, and Kentucky Stations, comparing whole with ground wheat when fed in well-balanced ra-

tions. In the trials reported in the first division of the table, the wheat was fed in the dry condition, while in the second division of the table are given the results when it was fed soaked. All the experiments except one were conducted under dry-lot conditions. The pigs which were fed their wheat dry weighed from 69 to 119 pounds when the trials began, while in the trials with soaked wheat the initial weight for the different experiments ranged from 107 to 138. All the experiments were continued until market weights were reached. In all but two of the dry-wheat experiments, the wheat was self-fed, free-choice.

Table 146. Whole versus Ground Wheat for Growing and Fattening Pigs
(Average 4 and 7 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*		*Comparative Values*
	lb.	lb.	lb.		
Whole wheat (dry) + tankage	5.70	1.411	W. Wheat	376	
			Tankage	28	100
			Total	404	
Ground wheat (dry) + tankage	5.66	1.482	G. Wheat	355	
			Tankage	27	107
			Total	382	
Whole wheat (soaked) + tankage	7.12	1.411	W. Wheat	485	
			Tankage	20	100
			Total	505	
Ground wheat (soaked) + tankage	7.69	1.676	G. Wheat	404	
			Tankage	15	108
			Total	459	

On the average, there was little difference in the rate of gain in favor of the ground wheat when fed dry. As shown by the amount of feed required for the gains, however, grinding had the effect of increasing the efficiency of the ration by about 7 percent. This is hardly sufficient to pay the cost if the service must be hired. When soaked and fed by hand, the ground wheat proved to be 8 percent more valuable than the whole wheat, and the rate of gain was considerably faster. The fact that grinding was not so beneficial when self-fed dry, in the first series of trials, suggests that the pigs may masticate the whole wheat more thoroughly when getting it in a self-feeder than when it is supplied to them twice a day by hand.

In two trials at the Michigan Station [38] Freeman obtained slightly better results with medium- and fine-ground wheat than with coarse-ground. The lots fed whole wheat gained faster than those fed ground wheat, but it required 17½ pounds in one and 10½ pounds in another more total feed to produce 100 pounds gain on the whole than on the ground wheat.

Soaking wheat. The question whether wheat should be soaked has not been clearly settled. Weaver of the Missouri Station [39] thinks ground wheat should be fed wet since less will be wasted. He also reports that there is no advantage in allowing the ground wheat to sour. Robison [40] reports that soaking wheat at the Ohio Station did not increase its value.

In the experiments with wheat which have just been considered, the wheat fed was sound and marketable. Wheat which has been injured in the dough stage by hot winds, drought, or frost, or which has been damaged by excessive rains during harvest is, of course, less valuable for feed than wheat which is well filled or uninjured. Likewise salvage wheat which has been damaged by elevator fire, water, and smoke is less valuable than sound wheat. Such wheat, however, has no value except for feed, and usually can be bought at a price considerably lower than its feed value. If not seriously damaged it may be fed alone straight, say in a self-feeder, although the better practice usually is to mix and feed with other grain. Ground wheat that has become stale through fermentation or injury by insects is less palatable than sound wheat and should be diluted as much as possible with other ground grain before feeding.

BARLEY

Barley is one of the most widely used cereals for swine feeding. In Canada and the European countries it is depended on for the production of the finest quality of bacon. In the United States its production is confined mainly to areas of the Pacific coast and the Northwest where its use in pork production is general. The tonnage production of barley in this country is about one-third the production of oats. Its price compared with corn and the other cereals has been such as to make it an economical feed in areas not too far removed from the source of production (see Fig. 55).

[38] V. A. Freeman, *Proc., Am. Soc. An. Prod.*, 1932.
[39] L. A. Weaver, Cir. 261, 1930.
[40] W. L. Robison, Bul. 607, 1939.

Composition of barley. Like the other cereal grains, barley is to be regarded more as a fattening than a growing feed, although less pronounced in this respect than corn. Its protein content is practically the same as that of wheat. In common with the other cereal grains also, it is very deficient in minerals and vitamins. To make a barley ration complete for growing and fattening pigs, therefore, it must have added to it a protein-rich supplement, a mineral mixture rich in calcium and common salt, and a source or sources of vitamins, such as green forage, fine-quality legume hay, or other sources. Weighing 48 pounds to the bushel, the fiber content of common barley is high compared with corn, wheat, or rye, and consequently is less digestible than these cereals.

Barley compared with corn. In Table 147 are summarized the results of 42 feeding trials in each of which ground barley was compared with shelled corn for growing and fattening pigs. Eight experiment stations participated in the study.[41] Thirty-three were conducted under dry-lot and nine under forage conditions. Only those experiments are included in which adequate supplements were fed and the rations full-fed according to appetite. In most instances the grain, protein supplements, and minerals were fed separately in a self-feeder. The feeds were fed dry in all cases. The supplements consisted of tankage, or a combination of tankage and a plant supplement. Alfalfa meal was included in the supplemental mixture in a number of the dry-lot trials. The pigs averaged 93 pounds at the start of the dry-lot experiments and 62 pounds in the trials on forage. In each case they were fed until they had practically reached market weight.

In only 3 of the 32 dry-lot trials and in none of those conducted under forage conditions did the pigs which received barley gain as rapidly as those fed corn. This was not due to any lack of palatability, however, for the barley ration was eaten in larger amounts than the corn ration. It was the result obviously of the higher fiber content and lower digestibility of the barley. This is the principal reason also why more feed was required in the production of a given gain on the ration containing the barley. In none of the trials was there as much corn as barley required for a unit of gain.

In three experiments Robison of the Ohio Station[42] compared ground barley with ground corn for growing and fattening pigs on

[41] South Dakota, Minnesota, Pennsylvania, Michigan, Oklahoma, Nebraska, Colorado, and Kansas.
[42] W. L. Robison, Bul. 607, 1939.

Table 147. Ground Barley versus Corn for Growing and Fattening Pigs
(Average 33 and 9 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*		*Comparative Values*
	lb.	lb.	lb.		
Shelled corn[a] + supplement (dry lot)	6.12	1.481	Corn	370	100
			Sup.	43	
			Total	413	
Ground barley + supplement (dry lot)	6.55	1.383	Barley	433	87[b]
			Sup.	41	
			Total	472	
Shelled corn + supplement + forage	5.47	1.487	Corn	338.0	100
			Sup.	30.2	
			Total	368.2	
Ground barley + supplement + forage	6.09	1.382	Barley	414.6	84
			Sup.	26.2	
			Total	440.8	

[a] In two of the trials the corn was ground.
[b] Not including charge for grinding.

rape pasture. Hand-fed with the trio-mixture as a supplement, the pigs which received barley gained almost as rapidly as those on corn and the feed consumed for a unit of gain gave to the ground barley a value equal approximately to 95 percent of the ground corn.

It would appear safe to conclude from these results that ground barley has a value, on the average, equal to 85 to 90 percent of corn for feeding growing and fattening pigs in the dry lot, and somewhat less than this when fed on forage. If we assume a charge of 10 cents a hundredweight to cover cost of grinding, a bushel of barley would have the values compared with corn as shown in Table 148.

Table 148. The Value of a Bushel of Barley at Varying Corn Prices

When a bushel of shelled corn (56 lb.) costs:	42¢	56¢	70¢	84¢	98¢	112¢	126¢
A bushel of ground barley (48 lb.) is worth:	31¢	41¢	51¢	61¢	72¢	82¢	92¢
A bushel of unground barley is worth:	26¢	36¢	46¢	56¢	67¢	77¢	87¢

If, instead of a uniform charge for grinding, the cost of this service had been increased as the price of the feed increased, as it usually does in practice, the value of the whole barley at the higher price levels would be somewhat less than that shown in the table.

Value of barley affected by weight. As always is the case, experimental feeding results are influenced by the quality or grade of the feeds involved. Results of a 4-year study by Wright of the South Dakota Station [43] in feeding three different grades of ground barley in comparison with shelled corn emphasize this fact. In each of the four years three weights of barley, 48, 40, and 31 pounds to the bushel, respectively, were fed to comparable groups of pigs in dry lots from initial weights averaging 95 pounds to final weights of about 235 pounds.

Compared with shelled corn and based on the pounds of feed required to produce a given gain, the three grades of ground barley had values compared with the shelled corn as follows: the barley weighing 48 pounds to the bushel had a value equal approximately to 93 percent of the corn; the barley weighing 40 pounds to the bushel was worth 88 percent as much; and the barley which averaged 31 pounds to the bushel had a value equal to 84 percent of the corn.

Barley should be ground. Early feeding trials by Thompson of the Oklahoma Station [44] showed that grinding increased the value of barley for growing and fattening pigs from 7 to 10 percent over unground barley. In three trials by Freeman of the Michigan Station pigs fed ground barley gained 17 percent faster than those fed whole barley, and required 12 percent less feed for the production of a unit of gain. It took three weeks longer to finish the pigs on whole barley. He also reported that when whole barley is self-fed with tankage self-fed, free-choice, that an unnecessarily large proportion of tankage was consumed.

Experimental results are not in agreement on the advisability of soaking whole barley for pigs. Some have been favorable to the practice, while in about an equal number of instances the results have favored feeding it dry. When ground, however, the experiments have quite uniformly shown faster and slightly more economical gains when fed wet or soaked by hand than when it was self-fed dry. Wetting seemed to be as beneficial as soaking between feeds. Some of the advantage from soaking as compared with feeding dry in the self-feeder

[43] Turner Wright, Bul. 366, 1942.
[44] Carl P. Thompson, 28th An. Rpt., 1919.

may be attributable to loss or waste of feed when fed by the latter method.

Barley and wheat compared. A summary of 4 trials by Robison [45] and 11 by Clark and Woodward of the Montana Station [46] indicate that ground barley has a value about equal to 88 percent of ground wheat for growing and fattening pigs. In all the trials, those fed wheat gained faster, on the average 19 percent, and required 11 percent less total feed for a unit of gain. In five of the experiments the pigs were on forage, and in six were confined to dry lots. Except in one trial, all rations were adequately supplemented. Headley of the Nevada Station [47] reported that 3 to 7 percent more barley than the low-protein wheat of the Pacific Coast was consumed for a unit of gain, the difference in efficiency being greatest when fed in dry lots and least on pasture, and greater when self-fed than when hand-fed.

RYE

Production and composition. Rye is a relatively unimportant grain crop in this country, its production being less than 1 percent that of corn; and of this, less than 30 percent is available for feed. Most of this crop grown in the United States is produced in North Dakota, Minnesota, South Dakota, and Nebraska. Rye is very similar to wheat in composition and, like the other cereal grains, is deficient in the amount and quality of its proteins, the quantity and kind of minerals, and in most of the necessary vitamins. As shown by many tests, it is not as palatable as other grains, and has a tendency to produce scours.

Rye and corn compared. Although the composition of rye would suggest as high a feeding value as is possessed by corn, experiments and experience have demonstrated that it is quite inferior to corn. In Table 149 are shown the averaged results of five trials at the Minnesota [48] and Ohio Stations [49] in each of which ground rye was compared with ground corn, with tankage, for growing-fattening pigs averaging less than 80 pounds in weight when the tests began. In the three Minnesota trials a mineral mixture in addition was fed in each lot. The grain and tankage were mixed in the proportion of about 10 to 1, and self-fed in most cases; in one they were self-fed, free-choice.

[45] W. L. Robison, Bi-Monthly Bul., Vol. 18, No. 2, 1935.
[46] R. L. Clark and R. R. Woodward, Bul. 434, 1946.
[47] F. B. Headley, Bul. 166, 1943.
[48] E. F. Ferrin and M. A. McCarty, Mimeo. Rpts., 1923 and 1924.
[49] W. L. Robison, Mimeo. Rpts., 1915 and 1917.

Table 149. Ground Rye versus Ground Corn for Growing and Fattening Pigs in the Dry Lot
(Average 5 Experiments)

	Daily Feed Consumption	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
			G. rye	507
Ground rye + tankage	4.89	0.880	Tankage	49
			Total	556
			G. corn	374
Ground corn + tankage	5.75	1.397	Tankage	38
			Total	412

Although the rye fed in these experiments was supposed to be of good quality and not infested with ergot, the pigs did not eat the rye ration with relish. Those getting rye consumed only 85 percent as much feed as those receiving corn. As a result of this, together with other and unknown causes, the pigs on the rye ration gained only 63 percent as rapidly as did those on the corn ration. These differences were quite consistently shown in the individual experiments. For producing 100 pounds of gain, 144 pounds less feed were required on the corn ration. Based on this figure, the rye as fed in these trials can be credited with a value equal only to 70 percent of that of corn.

As a result of the experiments at the Minnesota Station in which ground rye was fed as the only grain, along with tankage and a mineral mixture in the dry lot, Ferrin made the following observations:

For the first 30 to 40 days pigs fed ground rye and tankage make nearly as rapid gains as those receiving ground corn and tankage. Favorable results reported by other Stations have been the results of short experiments only. Our experience in feeding rye to hogs has demonstrated a lack of some essential food constituent or possibly a toxic effect from continued rye consumption. Pigs fed chiefly rye scour badly and at the end of 90 or 120 days' feeding may begin to lose weight. We have never succeeded in finishing a lot of pigs to an average weight of 200 pounds per pig on rye, tankage, and minerals under dry lot conditions.

In further studies, Ferrin [50] was unable to secure satisfactory gains by adding to the ration of ground rye, tankage, and minerals either cod-liver oil, alfalfa leaves, or casein, or a combination of these. No

[50] E. F. Ferrin, *Proc. Am. Soc. An. Prod.* 1925–1926.

significant improvement of the ration was obtained either when 5 percent of iron oxide was incorporated in the mineral mixture. In two trials, thorough cooking of the rye failed to be of any benefit. In 1928, however, Ferrin secured fairly satisfactory results when liver meal, which is rich in copper, was substituted for the tankage. Adding copper sulphate to the mineral mixture, however, was of no apparent help.

Fairly satisfactory results have been obtained at several stations from a ration of rye, properly balanced, when fed for limited periods to well-grown shotes. Edwards and Brown of the Michigan Station [51] secured gains averaging 1.23 to 1.48 pounds daily with pigs fed from a weight of 125 to 225 pounds in the dry lot on a ration composed of two parts ground rye to one part ground oats, balanced with tankage and a mineral mixture. In one test, six pigs to the lot, no significant differences were found to result from the method of feeding, such as self-feeding the mixture, soaking the mixture 24 hours and feeding by hand, or feeding the mixture wet in a slop. In one lot the feed mixture was fermented with yeast for 24 hours. Although the rate of gain was increased slightly, the cost of the gains was considerably greater as a result of the treatment.

Ferrin and McCarty of the Minnesota Station [52] obtained better results from a ration of one-half rye and one-half corn, and another of one-half rye and one-half barley, than from a ration in which rye was the only grain. In neither of the experiments, however, were the results considered satisfactory.

In one dry-lot trial by Wilson and Wright of the South Dakota Station,[53] 100-pound pigs were fed in the dry lot to the weight of 230 pounds on either shelled corn, ground rye, a mixture of one-half each of ground rye and ground corn, or a mixture of one-half each of ground rye and ground barley, in rations well balanced with tankage, alfalfa hay, and minerals. In this experiment the pigs getting the rye ration gained as rapidly as those on the corn ration. For producing a unit of gain the rye had a computed value equal to 94 percent of the corn. Better results were obtained from the mixture of barley and rye than from the mixture of corn and rye, or from rye alone. These experimenters also complained of the tendency of rye to scour the pigs.

Methods of feeding rye. Hays of the Delaware Station [54] in one trial obtained as good results in feeding a ration of ground rye and

[51] W. E. J. Edwards and G. A. Brown, Qt. Bul., Vol. 8.
[52] E. F. Ferrin and M. A. McCarty, Mimeo. Rpt., H-16, 1924.
[53] James W. Wilson and Turner Wright, Bul. 271, 1932.
[54] F. A. Hays, Bul. 124, 1919.

tankage free-choice style as when the ground rye was soaked and fed by hand and the tankage self-fed. Whole rye self-fed gave as good results as whole rye soaked 12 hours and fed by hand. The limited experimental studies indicate that grinding will be of sufficient benefit to more than pay for its cost.

The method of feeding rye to pigs which is most likely to give satisfactory results is in a ration such as two to three parts corn or other grain to one part ground rye, balanced with a protein supplement wholly or partly animal in character, a good mineral mixture, and fine-quality legume hay or green forage. When the appetite shows signs of failing, the rye should be further replaced with corn.

Generally speaking, rye should not be fed to pregnant sows. Feeding rye infested with ergot has been known to cause abortion. It should be considered safe for sows only when it is clean, of good quality, and when the amount fed is limited to one-third to one-fourth of the grain supply.

GRAIN SORGHUMS

The grain sorghums include kafir, milo, feterita, kaoling, and sorgo. Practically 90 percent of the acreage of these drought-resistant crops in the United States is grown in the three states of Texas, Oklahoma and Kansas. As shown in Fig. 55, their production, represented mainly by kafir and milo, amounts to about one-third that of barley and more than three times that of rye.

In chemical composition these grains are very similar to corn. They are rich in carbohydrates and particularly deficient in protein, minerals, and vitamins. Like the other grains, they are fattening in their properties and require to be supplemented with a protein concentrate, minerals rich in calcium and common salt, and vitamins for satisfactory results.

Kafir and corn compared for fattening pigs. In Table 150 are summarized the results of six experiments conducted at the Kansas and Oklahoma Stations,[55] in each of which ground kafir grain was compared with corn, which was ground in all but one instance. In all but one of the trials tankage alone, or tankage and shorts, was fed as a supplement. In one trial alfalfa hay was fed. All of the experiments were with well-grown shotes averaging 125 pounds at the start and about 225 pounds at the finish.

[55] Carl P. Thompson, Bul. 148, 1932.

Table 150. Ground Kafir versus Corn for Fattening Shotes, in Dry Lot
(Average 6 Experiments)

Rations	*Daily Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
Kafir + supplements	6.89	1.40	Kafir	457
			Tank. equiv.	35
			Total	492
Corn + supplements	6.39	1.46	Corn	410
			Tank. equiv.	28
			Total	438

In all excepting one of the Oklahoma experiments, the pigs receiving corn gained significantly faster than those getting kafir. The amount of feed eaten daily shows the kafir ration to have been as palatable as the corn ration. That kafir is not as efficient as corn, however, is shown by the amount of feed required for each unit of gain, there being a difference of 54 pounds of feed in favor of the corn ration in producing 100 pounds of gain. Converting the tankage and other supplements to terms of corn, the kafir had a computed value equal to 87 percent of that of corn.

In feeding trials conducted by Baker and Reinmiller of the Nebraska Station,[56] using pigs of an initial weight of 44 pounds fed to a final weight of 220 pounds, ground kafir had a computed value 91 percent and whole kafir 89 percent of that of corn.

In a forage experiment by Weber and associates of the Kansas Station,[57] it was concluded that almost as satisfactory gains, from the standpoint of rapidity and the amount of feed required to produce a unit of gain, can be made with ground kafir, tankage, and Sudan grass forage as from corn, tankage, and alfalfa forage, and the hogs will be practically as well finished.

Methods of feeding kafir. Thompson of the Oklahoma Station[58] made extensive tests of the various methods and forms of feeding kafir to pigs. His conclusions, based on the results of experiments covering four years, are quoted below.

> 1. Kafir corn fed in the head has not proven as efficient either from the standpoint of gains or cost of gain as threshed or ground kafir corn.

[56] M. L. Baker and C. F. Reinmiller, Bul. 323, 1939.
[57] A. D. Weber, B. M. Anderson, and H. W. Marston, Cir. 138, 1928.
[58] Carl P. Thompson, Bul. 165, 1927.

2. Soaking kafir corn heads has lowered the value of kafir corn 23 percent in the three experiments conducted.

3. Threshing kafir corn effected the saving of 33 percent in the amount of kafir corn required to produce 100 pounds of gain.

4. It required 7.4 percent more soaked threshed kafir corn than of dry fresh kafir corn to produce 100 pounds of gain.

5. Grinding effected the saving of 8 percent in the amount of feed required to produce 100 pounds of gain.

6. Self-feeding of either whole or ground kafir corn was satisfactory, but gave results only slightly different from hand feeding.

7. Fermenting whole kafir corn with yeast was only slightly superior to soaking whole kafir corn and did not give as good results as threshed kafir corn fed dry. Fermenting ground kafir corn with yeast caused a loss of 7.4 percent of its feeding value.

8. Yeast feeding proved unprofitable.

9. All the hogs excepting those fed on kafir corn heads made satisfactory gains, the most rapid gains being made by those receiving ground kafir corn.

10. Whether or not one can afford to grind kafir corn for hogs will depend upon the cost of grinding.

Milo compared with kafir and corn. In five dry-lot experiments at the Kansas Station [59] milo proved to be equal to if not superior to kafir for fattening pigs in the dry lot. Some of the experiments favored the kafir in economy of gains, and in about an equal number the milo was more efficient. Generally the rate of gain was a little faster on the kafir corn, but, on the average, 100 pounds of milo was equal to 104 pounds of kafir in producing gains.

When whole milo and shelled corn were compared in well-balanced rations for growing and fattening pigs in the dry lot at the Nebraska Station,[60] the results of three experiments showed the milo to have 88 percent of the value of corn, on the average. In palatability and rate of gain the two rations were practically equal.

In an 83-day dry-lot experiment in which two varieties of milo were compared with shelled corn, self-fed, free-choice, in well-balanced rations, Aubel of the Kansas Station [61] secured faster gains on slightly less total feed on the milo than the corn rations, although the milo-fed pigs consumed a larger proportion of tankage and alfalfa hay. He also found that grinding Wheatland milo did not increase its efficiency.

[59] E. F. Ferrin and H. B. Winchester, Cir. 89, 1921; T. R. H. Wright, Bul. 192, 1913; W. A. Cochel, *Kansas Industrialist*, May, 1915.
[60] M. L. Baker and C. F. Reinmuller, Bul. 323, 1939.
[61] C. E. Aubel, Cir. 41-II-2, 1941.

Feterita; cane or sweet sorghum; kaoling. Limited experimental data from the Kansas Station [62] indicate that fattening pigs in the dry lot will do practically as well on ground feterita as on ground milo. In three trials the pigs receiving milo gained a little faster, but the amount of feed required for a unit of gain was practically the same.

Experiments at the Kansas,[63] Nebraska,[64] and Oklahoma Stations [65] have shown that cane or sweet sorghum seed is considerably lower in value than corn for fattening well-grown pigs in the dry lot. The pigs getting corn gained 20 percent faster than those getting cane sorghum, and for producing gains the cane sorghum had a value equal to about 80 percent of that of corn. In one trial at the Nebraska Station a ration of one-half corn and one-half cane sorghum was fed in comparison with rations of corn alone and sorghum alone. In rate and cost of gains the results were intermediate between those obtained on the single grains.

Fattening pigs fed kaoling meal and alfalfa hay at the South Dakota Station [66] gained only 74 percent as rapidly as pigs fed corn meal and alfalfa hay, and required 25 percent more feed to produce a unit of gain. Somewhat better results were obtained with this feed, however, at the Kansas Station.

Darso. The feeding value of darso was found to vary widely in experiments conducted at the Oklahoma Station.[67] In the three trials this grain was ground and compared with ground corn for fattening well-grown pigs in the dry lot when fed in rations with tankage and minerals. The rate of gain on the corn ration averaged 5 percent faster than on the ration containing darso, and 71 pounds less feed were required for the production of 100 pounds of gain. This difference, after converting the tankage to terms of corn by multiplying by 2.4, gave to the darso a value equal to 83 percent of that of corn.

Proso millet seed. This grain, which has a composition much the same as corn, was compared with corn in three dry-lot experiments conducted by Wilson and Wright of the South Dakota Station.[68] The corn was fed whole and the proso ground, both self-fed, along with a supplemental mixture of tankage, alfalfa hay, and minerals, self-fed.

[62] T. R. H. Wright, Bul. 192, 1913; E. F. Ferrin and H. B. Winchester, Cir. 89, 1921.
[63] T. R. H. Wright, Bul. 192, 1913.
[64] W. P. Snyder and E. A. Burnett, Bul. 124, 1912.
[65] Carl P. Thompson, Bul. 148, 1923.
[66] James W. Wilson, Bul. 157, 1914.
[67] Carl P. Thompson, Bul. 148, 1923.
[68] James M. Wilson and Turner Wright, Bul. 316, 1938.

The pigs were well-grown, weighing about 130 pounds when trials started, and approximately 237 at the close.

The corn rations, on the average, produced faster gains by the difference between 1.75 and 1.60 pounds daily, and greater gains for a unit of feed. In efficiency, ground proso proved 92 percent as valuable as shelled corn.

HOMINY FEED

This corn by-product is nearly a complete substitute for corn in rations for swine. It may be designated either as *hominy feed, hominy meal,* or *hominy chop.* It is defined as follows by the Association of American Feed Control Officials: "Hominy feed is a mixture of corn bran, corn germ and a part of the starchy portion of either white or yellow corn kernels or mixture thereof, as produced in the manufacture of pearl hominy, hominy grits, or table meal, and shall contain not less than 5 percent of crude fat." It is white or yellow, depending on the color of the corn used.

Hominy is like corn in being rich in carbohydrates and low in protein, minerals, and many of the vitamins. The quality of protein, like that in corn, is inferior. Somewhat more of fiber and fat is contained in hominy feed than in corn. White hominy feed, like white corn, is wholly lacking in vitamin A. Both the white and yellow varieties probably are deficient in some of the B-complex vitamins and those associated with or contained in the APF factor. In feeding hominy feed, therefore, the same amount and kinds of supplements are required to balance it as would be necessary when corn is fed. Hominy feed usually will keep better in storage than ground corn because it is manufactured from corn which usually is kiln-dried.

Hominy feed compared with corn. In Table 151 are summarized the average results obtained in 18 experiments conducted at the Indiana,[69] Iowa,[70] Nebraska,[71] and Ohio Stations,[72] in each of which shelled or ground corn was compared with white or yellow hominy feed for growing and fattening pigs fed either in dry lots or on forage from an average beginning weight of 74 pounds to more than 200 pounds. Only those trials in which adequate protein and mineral supplements were fed are included. In all cases either tankage, tankage and alfalfa, or the trio-mixture was fed. Twelve of the experiments

[69] J. H. Skinner and C. G. Starr, Bul. 219, 1918; C. M. Vestal, Bul. [illegible]

[70] J. M. Evvard and R. Dunn, Mimeo. Rpt.

[71] H. J. Gramlich and E. L. Jenkins, Bul. 175, 1922.

[72] W. L. Robison, Mimeo. Rpts., 1934 and 1935.

were under dry-lot conditions, and six were on pasture. The rations were either self-fed or hand-fed, according to appetite.

Table 151. Hominy Feed versus Corn for Growing and Fattening Pigs
(Average 18 Experiments)

Rations	*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
	lb.	lb.	lb.	
			Corn	360
Corn + supplement	6.10	1.548	Tank. equiv.	34
			Total	394
Hominy feed +			Hominy	371
supplement	5.66	1.409	Tank. equiv.	31
			Total	402

In practically all cases the corn ration proved more palatable than the hominy ration. The pigs receiving corn consumed, on the average, 7.7 percent more feed daily and gained 9.8 percent faster than those getting hominy feed. Also, the hominy ration was not quite as efficient as the corn ration. Based on the amount of feed required to produce a given gain, the hominy feed in these trials had a value equal to 98 percent of that of corn.

Several experiments have shown that a combination of equal parts hominy feed and corn is equal if not superior to corn alone when fed in well-balanced rations to growing and fattening pigs.

Both white and yellow hominy feed were fed in the above trials. Any difference in feeding value between the two is obviously due to the presence of considerable vitamin A in the yellow and its absence in the white. Robison of the Ohio Station [73] concluded after two experiments in which the two were compared, that when fed in rations which included about 4 percent of alfalfa meal there was no significant difference between them.

High-fat hominy feed may produce soft carcasses. The amount of fat contained in hominy feed varies considerably. Robison reports that of 111 samples analyzed at the Indiana Station from 1907 to 1920,[74] 46 contained 8.5 percent of fat, 17 contained 7 percent or less, while 48 samples contained percentages between these. As given by Morrison, No. 2 corn contains an average of 3.9 percent of fat, and hominy

[73] W. L. Robison, Bul. 607, 1939.
[74] Buls. 209, 217, and 242.

feed (5 percent fat or more) 6.9 percent; low-fat hominy feed contains 4.3 percent of fat. Since corn fat is composed mostly of low-melting fats and oils, it is obvious that a ration in which hominy feed is the chief carbonaceous ingredient would have a tendency to produce soft carcasses.

Vestal and Shrewsbury of the Indiana Station[75] in seven dry-lot experiments with pigs fed from an average of 76 pounds to market weights, in each of which corn and hominy feed were compared in their effects on carcass quality, secured the results as summarized in Table 152.

Table 152. Effect of Hominy Feed on Carcass Grade

		Chilled Carcass Grades				
Rations	*Number of Carcasses*	*Hard*	*Medium Hard*	*Medium Soft*	*Soft*	*Oily*
Corn	81	73	7	1	0	0
Hominy feed	81	0	13	29	37	2

RICE BRAN; RICE POLISH; BREWER'S RICE

In the milling or production of polished rice for human consumption there are produced the by-products rice bran, rice polish, and brewer's rice, which are used as substitutes for corn in pig rations in Louisiana, Texas, Arkansas, and other states. Rice bran consists of the outer covering, or bran layer, of the kernel, and the germ, together with a small unavoidable amount of hull fragments. After the germ and the outer bran layer have been removed, the rice kernel is polished to remove the deeper or last bran layer. This powdery material is rice polish. For each 100 pounds of rough rice milled, about 63.9 pounds of whole or broken kernels, 12.9 pounds of bran, 3.7 pounds of polish, and 19.5 pounds of hulls are obtained.[76] Brewer's rice represents the small and broken pieces of the rice kernel, which are separated from the round kernels preparatory to milling. The average composition of these products, as given by Morrison,[77] are shown in Table 153.

Rice bran, it is to be noted, is very high in its fiber and fat content. It is immediately obvious that it is too bulky for rapid gains and likely to produce soft carcasses when fed as the principal part of the ration. Its protein supply is about the same as in barley and oats.

[75] C. M. Vestal and C. L. Shrewsbury, Bul. 501, 1944.
[76] Jenkin W. Jones and associates, Farmers' Bul. 1[illegible], 19[illegible].
[77] F. B. Morrison, *Feeds and Feeding*, 21st ed., Table I, Appendix, 19[illegible].

Table 153. Composition of Rice By-products, Corn, Hominy Feed, and Peanuts

Feeds	*Dry Matter*	*Protein*	*N-free Extract*	*Fiber*	*Fat*	*Calcium*	*Phosphorus*
	%	%	%	%	%	%	%
Rough rice, or rice grain	88.8	7.9	64.9	9.0	1.8	0.08	0.32
Rice bran	90.9	12.5	39.4	12.0	13.5	0.08	1.36
Rice polish	89.8	12.8	51.4	2.8	13.2	0.04	1.10
Brewer's rice	88.3	7.5	78.8	0.6	0.6	0.04	0.10
Corn No. 2	85.0	8.6	69.3	2.0	3.9	0.02	0.27
Hominy feed, 5+% fat	90.4	11.2	64.2	5.2	6.9	0.22	0.71
Hominy feed, low fat	89.7	10.6	67.4	5.0	4.3	...	...
Peanut kernel	94.6	30.4	11.7	2.5	47.7	0.06	0.44

Rice polish also is sufficiently high in fat to suggest trouble from soft pork, but is much lower in fiber and more concentrated in character than rice bran. Except for its high fat content, it is very similar to corn. Brewers' rice is more like corn in composition than either of the other two by-products. It is very hard and flinty in character, however, suggesting the need of grinding. All of these products, like corn and the other cereal grains, are notably deficient in minerals and, presumably, also in most of the vitamins.

Experimental feeding results. The following conclusions concerning the feeding value of rice by-products are indicated by the studies of Martin of the Arkansas Station,[78] Williams and Warren of the Texas Station,[79] and Robison of the Ohio Station.[80]

Neither rice bran nor rice polish is as palatable as corn. This probably is due to the high fat content and its tendency to become rancid in hot weather. Rations containing a low-level of either, with corn, however, proved more palatable than those containing corn without the rice products.

Like the grains, rice bran and rice polish must be supplemented with protein-rich feeds, as well as with minerals, and vitamins.

Both rice bran and rice polish, because of their high content of low-melting fats, produce soft carcasses when used as the chief fattening feeds in the ration and when fed for an extended period.

[78] Edgar Martin, Bul. 303, 1934.
[79] D. W. Williams and G. R. Warren, Bul. 313, 1923.
[80] W. L. Robison, Bul. 607, 1939.

A ration composed of 60 percent corn, 30 percent rice bran, and 10 percent of tankage gave very satisfactory gains and produced carcasses that generally graded hard or sligbtly soft. A mixture of 55 percent corn chop, 20 percent rice polish, 15 percent wheat shorts, and 10 percent of tankage fed the entire time produced too many soft hogs.

Robison says: "Inasmuch as 5.5 percent of softening fat is about the maximum in a ration that can be fed constantly without producing objectionably soft pork, unless their fat contents are below the average, not more than 16 percent of rice polish or 12.5 percent of rice bran can be incorporated in a corn and tankage ration with safety, so far as the production of pork of a satisfactory degree of firmness is concerned."

These studies indicated that the most successful practice generally was to limit the use of rice bran or rice polish to the early part of the growing-fattening period, followed during the last 8 or 10 weeks on hardening feeds, such as brewers' rice or other grains; or to restrict the amount fed so that the percentage in the ration did not exceed 12 to 16 percent.

Brewers' rice and tankage proved slightly superior to corn and tankage at the Arkansas Station when self-fed. Twelve parts of brewers' rice was consumed to one part tankage. Because of its low fat content, brewers' rice is a good hardening feed.

PEANUTS

Peanuts are a high-oil, protein-rich feed, more concentrated in character than any other known feed. Their concentration is due to the high fat or oil content, which constitutes 40 to 50 percent of the kernel, and to their low fiber content. They average about 30 percent of protein. Feeding experiments and chemical analyses indicate that the chief deficiencies of peanuts, in addition to the excessively high oil content, are concerned mainly with the supply of minerals, particularly calcium and common salt, and vitamins. Quality of the protein appears to be quite superior.

Low-grade and unmarketable peanuts are extensively used for pig feeding in the South, especially during the early growth period from weaning to a weight of about 125 pounds. Peanut oil meal is a low-fat, high-protein concentrate, the supplementing value of which has been considered in Chapter XIV. In Chapter XI the grazing of peanuts was discussed. We will consider here the feeding qualities of the

whole seed or kernel (without the hull) when used as the main part of the pig's ration and when fed under dry-lot conditions.

Summary of experimental results. The questions which concern the chemical deficiencies of peanuts and the amount and kind of supplements required to make a complete ration for pigs during the early part of their growth period, appear to have been settled in the main through the critical studies of Halverson, Hostetler, and Sherwood of the North Carolina Station.[81] These studies covered a period of 6 years and involved chemical feed analyses, carefully controlled individual and group-feeding trials, and a complete statistical analysis of the experimental data obtained. A good uniform quality of No. 2 or 3 grade shelled Virginia Runner peanuts were fed in the majority of the trials. The peanuts were variously supplemented with mineral mixtures, high-grade alfalfa meal, No. 1 tankage, or menhaden fish meal (55 percent protein), and wheat shorts. The pigs were home-bred and consisted of pure or crossbreds of the Poland China, Duroc Jersey, and Hampshire breeds.

Below are given the observations and conclusions of the authors in summarizing the results obtained:

> The data show that alfalfa meal and a mineral mixture are the only additional feeds necessary to produce satisfactory daily gains and that there is an economical consumption of peanuts per unit of gain when fed to pigs of average initial weights of 35 to 65 pounds.
>
> There was no apparent advantage in adding tankage (or fish meal) and wheat shorts to a ration consisting of peanuts, mineral mixture, and alfalfa meal.
>
> Animal proteins did not appear to be necessary for adequate daily gains in weight or economical utilization of feed when the mineral and vitamin deficiencies of the peanuts were supplied.
>
> The results shown in this bulletin include a statistical study of the individually fed pigs and the relative importance of the factors, in the lot fed pigs, of average daily gain, feed consumption per hundred pounds of gain, and the influence of the non-peanut protein on the proteins furnished by the peanuts. The study did not show any beneficial influence of the non-peanut protein, tankage (or fish meal), and wheat shorts.
>
> The results lead to the conclusion that the proteins and other nutrients in the ration consisting of shelled peanuts, mineral mixture, and alfalfa meal are adequate for growth in the pig; and when the mineral and vitamin requirements in a ration of peanuts are supplied, animal proteins do not appear to be necessary. The vitamin A supplied in these rations through alfalfa meal could, of course, be obtained under field conditions by the use of a green grazing crop.

Studies by Kirk and Crown of the Florida Station[82] emphasized the poverty of peanuts in calcium and common salt. When salt and

[81] J. O. Halverson, Earl H. Hostetler, and F. W. Sherwood, Tech. Bul. 41, 1931.
[82] W. G. Kirk and R. M. Crown, Bul. 372, 1942.

calcium carbonate were added to a peanut ration, in three experiments covering 118, 132, and 132 days, the gains were more than doubled compared with those obtained on peanuts alone, and the post-mortem studies showed the bones to have a higher specific gravity and greater breaking strength.

Peanuts produce soft pork. The soft-pork problem has always been a serious one in peanut-feeding areas. Since they contain 40 to 50 percent of fat or oil, and since this fat, like that of all plants, has a very low melting point, rations composed mostly of peanuts produce soft hogs. Extensive studies have been made by the U.S. Department of Agriculture [83] in cooperation with a number of experiment stations in the South for the purpose of determining ways and means of producing firm carcasses from pigs fed largely on peanuts. The progress that has been made in solving the problem is indicated by the following tentative conclusions:

> Peanuts grazed or self-fed in dry lot with or without minerals to pigs starting at weights ranging from 85 to 114 pounds and making gains of approximately 40 pounds or more on that feed through a period of approximately eight weeks will not produce firm carcasses at the usual market weight of 200 to 225 pounds attained by the subsequent feeding of corn with tankage after the peanuts. Results have shown, in fact, that gain on corn with tankage up to approximately 120 pounds, this maximum being produced during a feeding period of approximately 16 weeks' duration, following gains of 40 or more pounds on peanuts, usually will not produce hard or medium-hard hogs. As the gain on peanuts increases, the subsequent gain on corn with tankage necessary to produce a *certain degree of firmness likewise increases.*
>
> In comparing the results from the pigs having initial weights from 115 to 142 pounds with those from the lighter-weight pigs (referred to above) it is apparent that it is fully as difficult to produce firm hogs from the former as from the latter. There is an indication, in fact, that the hardening progresses more slowly with the heavier pigs, the gains on peanuts having been equal. The results strongly suggest that if a practical plan of producing firm hogs under this system of feeding is to be developed, it must make use of pigs weighing less than 85 pounds at the beginning of the peanut-feeding period.

CULL BEANS; CULL PEAS

As shown in Table 154, field beans and field peas are very much alike in composition. Both are legumes, quite extensively grown in the North and Northwest. Their protein content suggests that they may appropriately be used in the ration either as a partial substitute for the grain or as a supplement. They, of course, function as both whenever fed.

[83] O. G. Hankins, N. R. Ellis, and J. H. Zeller, Dept. Bul. 1492, 1928.

Fig. 59. The bacon bellies are most seriously affected by softening rations. The bacon at the left is from a hog which had been fed an excessive amount of soybeans; the one at the right is from a hog fed corn and tankage (*Ill. Exp. Sta., Bul.* 366).

Table 154. Composition of Field Beans and Field Peas [84]

Feeds	*Dry Matter*	*Protein*	*N-free Extract*	*Fiber*	*Fat*	*Calcium*	*Phosphorus*
	%	%	%	%	%	%	%
Field or navy beans	90.0	22.9	57.3	4.2	1.4	0.15	0.57
Field peas	90.7	23.4	57.0	6.1	1.2	0.17	0.51

Cull beans are made up of the broken, shrunken, discolored, or otherwise below-grade beans obtained in the sorting and grading processes preliminary to marketing. These are mostly of the white or navy variety grown for human use.

Investigations conducted by Edwards and Brown of the Michigan Station [85] indicate that cooked cull beans are an economical and fairly efficient feed when properly fed to growing and fattening pigs. In three dry-lot experiments they compared the protein supplementing efficiency of cooked cull beans with tankage for full-fed pigs from a weight of 105 to 200 pounds. The remainder of the ration consisted of ground corn, alfalfa hay, and a suitable mineral mixture. The proportions of tankage and beans fed in the respective rations were such as to ensure approximately the same nutritive ratio.

The pigs which received the ration supplemented with tankage gained 38 percent faster than those on the ration supplemented with the cooked beans, and the total amount of feed required to produce

[84] F. B. Morrison, *Feeds and Feeding*, 21st ed., Table I, Appendix, 1948.
[85] W. E. J. Edwards, and G. A. Brown, Cir. 21, 1927, and A. H. Leaflet 26, 1928.

100 pounds of gain was 424 and 457 pounds, respectively. One hundred pounds of beans had the computed value approximately of 43 pounds of tankage. Although the tankage ration was more efficient, the actual money cost was less on the ration containing the beans.

In other trials by the same investigators it was shown that a combination of cooked cull beans and tankage gave significantly faster and more economical gains than beans alone.

Studies by Beeson and Hickman [86] and of Lehrer and Hodgson of the Idaho Station [87] showed that when ground peas were substituted for 20 and 33 percent, respectively, of the rolled wheat in rations balanced with the trio-mixture and minerals for growing and fattening pigs in dry lots, the beans had computed values equal to 124 and 109 percent of the wheat. That ground cull peas can be used successfully as a partial or complete substitute for meat meal in self-fed, free-choice rations for pigs on pasture, was demonstrated in another experiment at the same station by Lehrer and associates.[88]

Results secured by McElroy of the University of Alberta [89] showed that peas could be successfully used in place of tankage to balance an oats-barley ration. He found that 103 pounds of peas had the replacement value of 27.6 pounds of tankage, 21 pounds of oats, and 63.8 pounds of barley in producing gains.

Warwick and associates of the Washington Station [90] in three years' trials found that rations of wheat and barley supplemented wholly or in part with cull peas produced as rapid and economical gains with growing-fattening pigs on Sudan grass pasture as when meat meal or soybean oil meal was used as the protein supplement. In two experiments under dry-lot conditions, rations balanced with cull peas produced faster and more efficient gains than the same rations balanced with meat meal.

POTATOES

Potatoes are extensively grown as a feed crop in Germany and other European countries. In the United States they usually are fed profitably only when there is an abnormal oversupply and the price is low compared with other feeds, or when cull or unmarketable grades are available.

[86] W. H. Beeson and C. W. Hickman, Cirs. 105 and 106, 1945
[87] W. P. Lehrer and C. W. Hodgson, Cir. 107, 1946.
[88] W. P. Lehrer, W. H. Beeson, and Alvin Wilson, Cir. 103, 1946.
[89] L. W. McElroy, Mimeo. No. 130, 1945.
[90] E. J. Warwick, T. J. Cunha, and M. E. Ensminger, Bul. 500, 1948.

Potatoes are composed mostly of starch and water. On the dry-matter basis, they are even more carbonaceous than corn. They contain about 80 percent of water and, like the grains, are very deficient in calcium, common salt, and vitamins. They are one of the few feeds that require cooking for satisfactory results. It has the effect of increasing their digestibility and improving greatly their palatability.

Potatoes compared with corn. Studies which have been made by Wilson and Kuhlman of the South Dakota Station[91] demonstrated very well the value of cooked potatoes when fed under favorable conditions to well-grown fattening pigs. In four dry-lot experiments they compared a ration of corn and tankage with one of corn, cooked potatoes, and tankage, about three parts of potatoes being fed to one part of corn. The potatoes generally were of the cull grade. The pigs averaged 113 pounds in weight at the beginning of the trials.

Good gains were made on both rations: they averaged 1.38 pounds daily on the corn-tankage ration and 1.197 pounds on the corn-potato-tankage ration. For producing a unit of gain 338 pounds of potatoes had a calculated value equal to 100 pounds of corn.

This is a somewhat higher value for potatoes than was shown in earlier experiments at the Wisconsin Station and the Ottawa Experimental Farms. Also, Henry and Morrison's summary of Fjord's experiments at Copenhagen (Denmark) gave 400 pounds of cooked potatoes the value of 100 pounds of mixed grain. English tests indicate that 4 pounds of cooked potatoes will replace 1 pound of barley meal in the diet of the bacon pig.[92]

In the South Dakota studies pigs gained less than half as fast on uncooked as on cooked potatoes, and 100 pounds of the cooked potatoes proved equal to 138 pounds of raw potatoes. These investigators suggest that for best results cooked potatoes should not replace more than one-half the corn in the ration, that the potatoes should be salted, and that no more water be used in cooking than is necessary. They also suggest the advisability of making available alfalfa hay in winter feeding.

Sweet potatoes, owing to their lower water content, have a somewhat higher feeding value than the Irish variety, and are more palatable. They have, however, the same chemical deficiencies in their protein and mineral content. Sweet potatoes can be most profitably used when the pigs are allowed to graze them, according to the custom in the South (see Chapter XI, page 313).

[91] James W. Wilson and A. H. Kuhlman. Bul. 209. 1924.
[92] H. E. Woodman and R. E. Evans, *Jr. Agr. Sci.*, Vol. 33, 1943.

Dehydrated potatoes. Dehydrated potatoes, containing about 10 percent of moisture, are now available in variable amounts in the form of meal or flakes. As reported by McMillen and associates of the Michigan Station [93] feeding experiments testing their value in comparison with corn or barley have been made at the Minnesota, California, North Dakota, and Michigan Stations.

Results of these studies indicate that for growing and fattening pigs as much as 30 percent of the corn may be replaced with potato meal or flakes, pound for pound, in otherwise well-balanced rations with satisfactory results as measured by the rate and economy of gains. When fed at this level at the Minnesota Station, a pound of potato meal was equal approximately to a pound of corn.

Hughes of the California Station concluded that potato meal could be successfully fed with barley at the level of 25 percent of the ration to all classes and weights of hogs with satisfactory results. The North Dakota investigators found that partly grown shotes could efficiently use a ration in which dehydrated potatoes replaced one-half the corn. The results generally suggested that pigs over 120 pounds are able to use potato meal or flakes to better advantage than younger pigs.

As a result of their studies at Cambridge University, Woodman and Evans [94] recommend that potato meal (dehydrated potatoes) be limited to 10 percent of the total ration for pigs up to 60 pounds in weight, to 20 percent from 60 to 100 pounds, and to a maximum of 30 percent at 150 pounds. Excessive amounts for young pigs gave rise to digestive disturbances and scouring. The same authors made chemical and digestion experiments with *potato peelings.* They found that 4.65 pounds of peelings contained as much digestible nutrients as 4 pounds of potatoes, which suggests that the parings are worth about 86 percent as much as potatoes in pig rations.

ROOTS

Roots are of little economic importance in the production of pork in the United States, first, because the weather and labor conditions required for their production are such as to make them less profitable than the cereal grains, and second, because of their watery character they are not so well adapted to the simple digestive system of the pig as are the more concentrated grains. In Canada and the European countries, and in some sections of our own Northwest, however, roots

[93] W. N. McMillen, G. A. Brown, and R. W. Luecke, Qt. Bul., Vol. 30, No. 4, 1948.
[94] H. E. Woodman and R. E. Evans, *Jr. Agr. Sci.*, Vol. 33, 1943.

are used as adjuncts to the cereal grains, particularly for the maintenance of the breeding herd.

The roots commonly fed to hogs—sugar beets, mangels, carrots, and rutabagas—contain from 84 to 90 percent of water. One hundred pounds of roots supply only one-fifth to one-eighth as much dry matter as the same weight of corn. Like the grains they are carbonaceous in character. They are very deficient in minerals, especially in calcium, and have little or no value as sources of vitamins, although carrots are rich in vitamin A. Because of their high water content, roots are laxative in their effect.

When chopped into small cubes, or otherwise prepared in suitable form, and fed in amounts to replace no more than about one-fourth of the grain portion of the ration, roots will have a value compared with the grains about equivalent to the dry matter supplied. This is to say that, when fed under favorable conditions, 5 to 8 pounds of roots would be required to equal in feeding value 1 pound of grain. Unlike potatoes, roots give better results when fed raw than when cooked.

CANE MOLASSES

Cane molasses, or blackstrap, is strictly a carbonaceous concentrate, sufficiently similar to corn in composition to suggest the possibility of its use as a partial substitute for this grain in fattening rations. Because of its higher water content, however, 100 pounds of molasses contains only about 70 percent as much digestible matter as an equal amount of corn. Its protein content is considerably less than in corn and its nutritive ratio consequently much wider. The carbohydrates of corn are largely starch, whereas in molasses they consist mostly of sugars. Although sugar is more readily soluble than is starch, the digestive system of the pig is apparently better adapted to the use of starch than of sugar.

The low price of molasses which has prevailed in recent years has brought about some renewal of interest in the feed as a substitute for corn in rations for growing and fattening pigs. As early as 1910, Burns of the Texas Station[95] reported better results from corn alone than from rations in which blackstrap replaced 25 or 50 percent of the corn, for fattening well-grown pigs. In one trial at the Oregon Station[96] with well-grown shotes fed in the dry lot, cane molasses proved equal to barley when fed in a ration composed of 72 percent barley, 20 per-

[95] John C. Burns, Bul. 131, 1910.
[96] E. J. Fjeldsted and E. L. Potter, Bul. 165, 1919.

cent molasses, and 8 percent of tankage. In another experiment at the same station, replacing one-fifth of the mill run with an equal weight of molasses increased the consumption of feed and resulted in a value for the molasses equal to that of mill run. These investigators reported that molasses purchased in barrel lots cost 50 percent more than when bought in large volume and delivered in tank cars. Large commercial feed manufacturers obtain their supplies in the latter form. Hackedorn and Sotola of the Washington Station [97] found cane molasses equal in value to barley when the molasses replaced one-half the barley in rations for fattening pigs on pea forage. When fed to pigs in the dry lot, however, molasses proved less efficient than barley when replacing one-half of the barley at the rate of 1½ pounds of molasses for 1 pound of barley. At the Mississippi Station [98] a ration of five parts corn, five parts shorts, and one part tankage gave slightly faster and cheaper gains than a ration in which two to three parts of the corn were replaced by blackstrap molasses at the rate of 1½ pounds of molasses for 1 pound of corn in a 51-day feeding period with well-grown shotes in the dry lot.

Experiments covering two years at the Wisconsin Station by Bohstedt and associates [99] showed cane molasses to be worth somewhat less than corn for growing fattening pigs, while its cost was considerably greater. They obtained better results when the molasses was mixed with the grain portion of the ration and the mixture self-fed separately than when the molasses was mixed with the protein supplement and self-fed.

Carroll of the Illinois Station [100] recently conducted an experiment in which three lots of 20 pigs each were fed in open fallow lots from a beginning weight of 70 pounds to a finishing weight of about 200. The first lot was fed a well-balanced feed mixture composed of corn, tankage, soybean oil meal, alfalfa meal, and salt. In the second lot cane molasses was substituted for enough of the corn to make it amount to 20 percent of the ration mixture. Enough molasses was substituted for the corn in the third lot to make it represent 30 percent of the mixture. The proportions of tankage and soybean oil meal were varied so that the three rations were practically identical in protein content. In all cases the rations were mixed and fed by hand, according to appetite. The results are summarized in Table 155.

[97] H. Hackedorn and J. Sotola, Bul. 109, 1922.
[98] B. Barnett and C. J. Goodell, Bul. 218, 1923.
[99] G. Bohstedt, Bul. 428, 1934 and Bul. 430, 1935.
[100] W. E. Carroll, Information to the author.

Table 155. Cane Molasses as a Substitute for Corn for Growing and Fattening Pigs

Rations		*Daily Feed Consumption*	*Daily Gain*	*Feed Required for 1 Cwt. Gain*	
		lb.	lb.	lb.	
Feed mixture	100%	7.00	1.79	Feed mixture	392
Feed mixture +	80%	6.84	1.44	Feed mixture	381
Molasses	20%			Molasses	95
				Total	476
Feed mixture +	70%	6.97	1.38	Feed mixture	362
Molasses	30%			Molasses	145
				Total	507

The substitution of molasses for corn in these proportions was clearly unprofitable. Soon after the experiment began, it was evident that the pigs receiving molasses were not thriving. This was shown, not only by their slower gains and lack of condition, but also by their rough hair coats and lack of appetite. Those fed molasses required, respectively, 20 and 27 days longer to attain finished weights, and for producing a unit of gain 100 pounds of molasses had an average value in the two lots equal only to 16⅔ pounds of the feed mixture.

Aubel's results at the Kansas Station [101] showed that the addition of 1, 2, or 3 pounds of molasses daily per head to a ration of shelled corn, tankage, and alfalfa hay for pigs in the dry lot increased the cost of gains even with corn priced at $1.26 per bushel and molasses $26 per ton. At the Florida Station [102] pigs fed 10 percent of blackstrap molasses in a ration of corn, fish meal, alfalfa leaf meal, and minerals made practically the same gains but required more feed for a unit of gain than those fed the same ration without the molasses. Feeding as much as 20 to 40 percent of molasses in the ration decreased the rate and increased the cost of the gains.

Results obtained in an 81-day feeding trial with well-grown fattening pigs by Ferrin of the Minnesota Station [103] showed that cane molasses was eaten with greater relish and produced faster and cheaper gains when fed with ground oats than with ground corn. Pigs getting ground oats as the only grain in a well-balanced ration consumed molasses sufficient to constitute 23 percent of the ration;

[101] C. E. Aubel, Hog Cir. 37A, 1937.
[102] W. G. Kirk and R. M. Crown, Bul. 423, 1947.
[103] E. F. Ferrin, Mimeo. H-69, 1936.

those fed half ground oats and half ground corn were successfully fed as much as 20 percent of molasses in the ration; in the lot in which ground corn was the sole grain fed, the pigs could be induced to eat no more molasses than sufficient to represent 13 percent of the ration without causing a serious reduction in feed consumption. The results suggested that the higher fiber content of the oats rations was related in some way to the better accommodation and use of the sugar-rich molasses. In a later trial, using younger pigs, Ferrin [104] fed 1.38, 1.52, and 1.60 pounds of cane molasses per pig daily, respectively, to three groups of pigs. Ground corn alone was fed in the first lot, equal parts ground corn and ground oats in the second, and ground oats alone in the third lot, in addition to a protein supplement and mineral mixture. The pigs fed the corn-molasses ration made the fastest gains and required the least amount of feed to produce a unit of gain, but they showed a greater tendency to scour than those fed the oats-molasses ration.

The failure of pigs to do well on rations containing considerable molasses may be due in part to the physiological fact, observed in humans, that the ingestion of large quantities of sugar is likely to cause irritation of the stomach and result in excessive acid fermentations.

CITRUS MEAL

Dried citrus pulp or citrus meal is defined by the Association of American Feed Control Officials as the dried and ground peel, residue of the inside portions, and occasional cull fruits of the citrus family with or without the extraction of part of the oil of the peel. If calcium oxide or calcium hydroxide is added as an aid in processing, the maximum percentage present, expressed as calcium (Ca), must be stated.

Cannery refuse consists of the peel, rag, and seed. They are high carbohydrate products, containing 85 to 90 percent of dry matter, around 5 percent of protein, 65 to 70 percent of nitrogen-free extract, 11 percent of fiber, 1 percent of fat, and 4 percent of ash. The amount of this annually produced in the state of Florida from 1929 to 1934 was as follows: from grapefruit, 64,040 tons; from oranges, 65,642 tons.[105]

Kirk and Crown of the Florida Station [106] fed grapefruit meal to

[104] E. F. Ferrin, Mimeo. 11-70, 1937.
[105] W. M. Neal, R. B. Becker, and P. T. Dix Arnold, Fla. Exp. Sta. Bul. 275, 1935.
[106] W. G. Kirk and R. M. Crown, Bul. 428, 1947.

three groups of pigs in the dry lot, weighing 67 pounds at the start to a final average weight of 212 pounds at levels of 5, 10, and 20 percent of the ration, respectively. The basal ration was made up of corn meal, fish meal, and minerals. They found that the ration in which 5 percent of the grapefruit meal replaced an equal amount of corn, the results in rate and economy of gains were similar to those obtained on the check ration. Feeding more than 5 percent caused digestive disturbances, and decreased the rate and increased the cost of the gains.

XVI *The Cost of Producing Pork*

The most important factor affecting profits in pork production is the cost of production. The other factor is the amount and quality of the finished product, or its sale value in relation to its cost. In this chapter chief consideration will be given to the cost-of-production studies which have been made in the Corn Belt and to the improvement in feeding and management practices which they suggest.

PRODUCTION COSTS BASED ON FARM COLLECTED DATA

Cooperative studies made by the U.S. Department of Agriculture and the Illinois and Iowa Experiment Stations from 1913 to 1926 supply data on the costs of production on typical Corn Belt areas as summarized in Table 156. There were 633 farms included in the survey on which cost account records were taken by trained observers for the entire hog enterprise. The figures represent the rough averages of five selected studies.[1]

Table 156. Summary and Distribution of Costs of Producing 100 Pounds of Live Market Pork Prior to 1926

Concentrates fed for each 100 pounds of pork produced	474 lb.
Percentage of feed to total costs	79%
Percentage of labor to total costs	7%
Percentage of other costs to total costs	14%

More recent studies by Wilcox and associates of the Illinois Station[2] of the cost of producing pork on 61 Illinois farms in 1945, 1946, and 1947 showed the following with respect to the average feed and other costs for 100 pounds of live market pork:

[1] H. C. M. Chase and R. C. Ross, Ill. Exp. Sta., Bul. 301, 1927; John A. Hopkins, Ia. Exp. Sta., Bul. 255, 1929; R. H. Wilcox, W. E. Carroll, and T. G. Hornung, Ill. Exp. Sta., Bul. 390, 1933; Oscar Steason and R. H. Wilcox, U.S.D.A., Dept. Bul. 1381, 1926.
[2] R. H. Wilcox and A. C. Rowe, Mimeo. Rpt., 1947.

Total feed concentrates, lb.	503
Percentage of feed to total costs	75.9
Percentage of labor to total costs	10.3
Percentage of other costs to total costs	13.8

The largest item in the cost of producing pork is feed. Approximately 80 percent of this is required to grow and fatten the weaned pigs to a weight of around 225 pounds, and 20 percent to maintain the breeding herd and raise the pigs to weaning age.

Figures tabulated by Atkinson and Klein of the U.S. Bureau of Agricultural Economics [3] from data reported by the Farm Business Association of Illinois, Iowa, Minnesota, and Wisconsin from 1928 to 1942 showed the amount of concentrates consumed by the entire hog enterprise for each 100 pounds of market pork to be as shown in Table 157.

Table 157. Concentrates Consumed per 100 Pounds of Marketable Live Weight, as Reported by Farm Business Associations

	Number of Farms	*Pounds of Concentrates per 1 Cwt. of Marketable Gain*
Illinois	3852	428
Iowa	2498	442
Minnesota	3268	487
Wisconsin	103	450
Totals and average	9721	452

These results in the average show a larger production of pork from a given amount of feed than those obtained in the earlier studies reported in Table 156. On the average, 4.6 percent less feed was required to produce 100 pounds of live pork in the later than in the earlier studies. The feed fed included that consumed by the breeding herd as well as that given the growing and fattening market pigs.

Based on the results obtained in 12 selected experiments conducted at five Corn Belt stations with growing and fattening pigs, together with those obtained by Oscar Steanson in a study of cost-production records in herds containing more than 10,000 sows, Atkinson and Klein [4] obtained the figure 411 as representing the total number of pounds of concentrates required in the production of 100 pounds of finished market hogs. From the author's study of the items of cost, as

[3] L. J. Atkinson and John W. Klein, U.S.D.A. Tech. Bul. 894, 1945.
[4] *Ibid.*

detailed later in this chapter, it is calculated that 410 pounds of concentrates were required to produce 100 pounds of live market pork in the system of production (C) when the sow is kept until four years old, produces a total of six litters and averaging seven pigs raised to the litter.

Increased feed costs with increased marketing weight relatively unimportant. As discussed in Chapter VII (see Table 40) the amount of feed required to produce 100 pounds of gain live weight increases as the age and weight of the pig increases. But when the entire feed cost is considered, the feed fed the breeding herd as well as that fed the pigs from weaning to the respective market weights, the increase in feed costs is surprisingly small.

Atkinson and Klein's figures based on their comprehensive study, *Feed Consumption and Marketing Weight of Hogs*,[5] as shown in Table 158, give a clear demonstration of this principle.

Table 158. Feed Consumption of Hogs per 100 Pounds Live Weight Marketed

Market Weight, Pounds	*Consumption of Concentrates per 100 Pounds Live Weight*			
			Index Numbers (225 lb. Butcher Hog = 100)	
	Feed Units [a]	*Pounds*	*Feed Units*	*Pounds*
200	466	407	99.5	99.0
225	469	411	100.0	100.0
250	472	417	100.7	101.3
275	477	423	101.7	103.0
300	483	431	103.0	104.8

[a] Feed unit values used here were: corn, 1.00; soybean oil meal, 1.75; tankage, 2.50; dried skim milk, 2.00.

These authors say: "Hogs marketed at 200 pounds consume about one-half of 1 percent fewer feed units per 100 pounds of live weight than do hogs marketed at 225 pounds. Hogs marketed at 250 pounds require about 1 percent more, at 275 pounds about 2 percent more, and at 300 pounds 3 percent more feed units per 100 pounds of live weight than 225-pound hogs. Thus, varying the market weight of hogs by as much as 100 pounds has little effect on the feed consumption per 100 pounds of live weight marketed."

Only feed costs were considered here. Since feed represents only 75 to 80 percent of the entire cost of production, and since the overhead is little, if any, greater in producing a 300- as compared with a

[5] L. J. Atkinson, and John W. Klein, U.S.D.A., Bu. Agr. Ec., Tech. Bul. 894, 1945.

200-pound market hog, it is apparent that the above slight differences would be further reduced when the entire costs are taken into consideration.

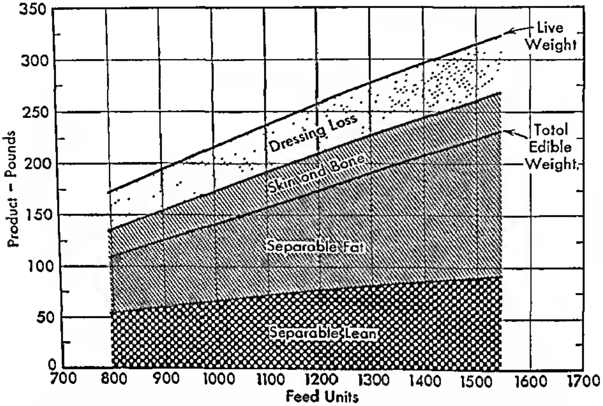


Fig. 60. Relation of feed costs to the amount and nature of the gains. As the pig grows and fattens the proportion of fat increases and all other parts, including the lean, decrease *(courtesy, U.S.D.A., Bureau of Agr. Economics).*

The relation between the total feed costs and the amount and nature of the gain of growing and fattening pigs marketed at weights of 175 to 325 pounds is shown diagrammatically by Atkinson and Klein [6] in Fig. 60.

Factors responsible for differences in costs. The summarized results of these farm management cost-of-production studies show general averages only, which is valuable information. What is more important, however, was the wide variation in the costs which was found among the individual farms, the result of the feeding, and management practices followed. For example, in the Illinois studies of 1924, 1925, and 1926, on one-third of the 106 farms which had the low-production costs, 100 pounds of pork were produced, on the average, at a cost of $6.22, while on the third having the high-production costs it required

[6] *Ibid.*

$10.24.[7] Wider variations still were found, of course, on the individual farms. The chief value of such studies to the producer is to be found in the reasons why some farmers were able year after year to produce pork economically while others were not. Although it was not the purpose of any of these investigators to study in detail the causes responsible for the wide variation in costs, the following were noted as significant factors:

1. Better feeding methods generally were followed on the low-cost farms. Better judgment was used in the purchase and use of protein and mineral supplements; more intelligent use was made of forage crops and legume hay for winter feeding; the ration of the pregnant sows was more generally balanced, and the amount fed was more carefully regulated. These improved feeding practices were reflected in lower costs for the maintenance of the breeding herd, better condition of the sows at farrowing time, faster gains of the growing and fattening pigs, and less feed for a unit of gain. They were also partly responsible for a lower death rate among the nursing pigs.

2. Sanitation and disease control were more generally practiced on the low-cost farms. The sows farrowed in cleaner houses, the young pigs were kept away from old hog lots and on clean pasture or clover, and vaccination against cholera was more common. As a result, the losses among the suckling pigs due to scours, necrotic infections, worms, anemia, etc., were much less than on the high-cost farms, the number of pigs raised per sow was greater, and the vigor and feeding capacity of the pigs such that faster and cheaper gains were made. . . .

influenced by her care and feeding. The type and breeding of the boar used also affects the vigor and capacity of the pigs for rapid and economical gains. Such stock selected on the basis of family and breeding performance is essential for the cheapest cost of production as well as to give to the finished product the highest selling value.

5. Observations made in the Illinois studies indicated no consistent difference between gilts and tried sows in the economical production of pork, although the practice of carrying over spring-mature sows to farrow the following spring, in the one-litter system, was shown definitely to be unprofitable. Farms producing two litters annually showed lower investment in breeding stock and equipment for a given amount of pork produced than the single-litter farms, although heavier death losses occurred on the two-litter farms.

6. The size of the swine enterprise also was found to be a factor. The studies showed lower costs of production, especially for labor and overhead, on those farms which produced the larger numbers or where

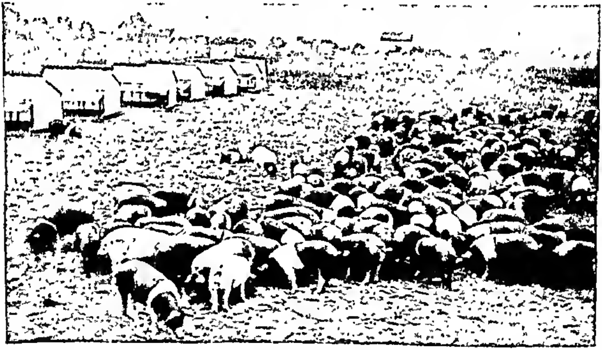


Fig. 61. The three interesting features of this picture are (a) a uniform lot of quality pigs nearing market finish which show the results of careful breeding and good feeding; (b) a good type of colony house adapted to both winter and summer use; and (c) a field of alfalfa to which the pigs have had access during the summer.

the hog enterprise was conducted as the major activity of the farm. It is reasonable to suppose that the larger producers who specialize in pork production would, because of their interest and greater skill,

be more efficient in their feeding and management operations than those whose chief interest is centered in some other class of livestock, or where, due to feed or other farm conditions, large numbers are not justified. In other words, the larger producers produce pork at a lower cost, as a rule, chiefly because of less overhead, because their farms are better adapted to the enterprise, and because, as a rule, they are better hogmen.

COST STUDIES BASED ON EXPERIMENTAL FEEDING DATA

In the following pages is reported a study of costs which differs in its approach from those which have been made in farm management surveys. The feed costs are based on experimental results obtained with fairly well-balanced rations and under good management conditions, as reviewed in earlier chapters. They do not represent the actual costs for the average farm, but should be comparable to those obtained under the best of farm conditions. The charge for labor was calculated on the basis of one man devoting his entire time to the hog enterprise and at a wage scale considerably higher than that paid average farm labor. The other costs represent tractor use, veterinary service, interest, depreciation, and insurance on buildings and general equipment, and risk of loss. Building costs and depreciation were considerably greater than they are believed to be for the average farm equipment. No credit was taken for the manure produced.

The plan employed in this study and the data on which the costs are based are shown in detail below. Three general systems of production are considered: (a) when the pigs are produced by gilts only; (b) when the pigs are produced by sows kept until 4 years old and producing a total of five litters; and (c) when produced by sows farrowing two litters annually after maturity or a total of six litters.

I. Feed cost of growing and finishing market pig (30 to 225 pounds):
  1. With good forage crops,
    (a) 663 pounds of concentrates (grains were figured at 2½ cents a pound; meat scraps, fish meal, etc. at 5 cents a pound; oil meals at 3½ cents a pound) @ 2½¢ per pound $16.57
    (b) One-fifteenth acre good forage @ $20 per acre .... $ 1.33

  Total feed costs $17.90
  2. Under dry-lot conditions,
    753 pounds of concentrates @ 2½¢ per pound $18.82

II. Other costs of growing and finishing market pig (30 to 225 pounds)
    (a) Vaccination and other veterinary costs .... $ 0.65
    (b) Labor, man and tractor .... $ 1.25

(c) Share of interest, depreciation, and insurance on buildings and general equipment	$ 2.50
(d) Risk of loss after weaning (4 percent)	$ 0.60
Total other costs	$ 5.00
Total feed and other costs of growing and finishing market pig (30 to 225 pounds),	
1. With good forage crops	$22.90
2. In dry lot	$23.82

To the above must be added the cost of the pig at weaning time. This will be determined mainly by the cost of maintaining the breeding herd and the number of pigs raised to the litter.

A

When Produced by Gilt. After Weaning Her Litter Gilt Is Fattened and Sold for Pork.

I. Feed cost of growing the sow pig to breeding age (30 to 200 pounds):	
(a) 566 pounds of concentrate @ 2½¢ per pound	$14.15
(b) One-twelfth acre of good forage @ $20 per acre	$ 1.66
II. Cost of feeding gilt from breeding to farrowing time (450 pounds of concentrates @ 2½¢ per pound)	$11.25
III. Cost of feeding sow (gilt) and nursing average litter (700 pounds of concentrates @ 2½¢ per pound)	$17.50
Total feed costs	$44.56
IV. Other costs of raising gilt and maintaining her until her litter is weaned:	
(a) Charge for original weanling sow pig (estimated)	$ 8.00
(b) Risk of loss (5 percent)	$ 1.25
(c) Vaccination and other veterinary costs	$ 1.50
(d) Interest, depreciation, and insurance on buildings and general equipment, etc.	$ 3.00
(e) Bedding	$ 0.70
(f) Boar service	$ 3.00
(g) Labor	$ 7.00
Total other costs	$24.45
Total feed and other costs of litter at weaning time	$69.01
V. Value of gilt for pork (300 pounds @ $12 per cwt. minus cost of 50-pound gain @ $10 per cwt.)	$31.00
Net cost of weaned litter by gilt	$38.01
The cost of each weaned pig would therefore be as follows:	
(a) With 4 pigs raised to the litter	$ 9.50
(b) With 5 pigs raised to the litter	$ 7.60
(c) With 6 pigs raised to the litter	$ 6.33

(d) With 7 pigs raised to the litter	$ 5.43
(e) With 8 pigs raised to the litter	$ 4.75

B

When Produced by Mature Sow Kept until Four Years Old and Producing Three Litters Every Two Years after Maturity (Total of Five Litters). After Weaning Her Fifth Litter She Is Fattened and Sold for Pork.

I. Feed cost of raising the sow pig to breeding age (30 to 200 pounds)	$ 15.81
II. Cost of feeding gilt during gestation	$ 11.25
III. Cost of feeding sow (gilt) and nursing litter	$ 17.50
IV. Cost of feeding open sow during two summers	$ 14.00
V. Cost of feeding pregnant sow during three winters (1575 pounds of concentrates @ 2½¢ per pound)	$ 39.37
VI. Cost of feeding pregnant sow during one summer gestation	$ 11.40
VII. Cost of feeding sow and four nursing litters (3000 pounds of concentrates @ 2½¢ per pound)	$ 75.00
Total feed costs	$184.33
VIII. Other costs of raising and maintaining sow four years:	
(a) Charge for original pig	$ 8.00
(b) Risk of loss (1¾ percent annually)	$ 3.48
(c) Vaccination and other veterinary costs	$ 4.00
(d) Share of interest, depreciation, insurance on buildings and equipment for four years	$ 12.00
(e) Five boar service fees	$ 15.00
(f) Labor for four years	$ 30.00
Total feed plus other costs of five litters at weaning time	$256.81
IX. Value of sow for pork (450 pounds @ 10¢ per pound minus cost of 50-pound gain)	$ 39.50
X. Total net cost each weaned litter produced by sow raising three litters every two years after maturity	$ 43.46

The total cost of each weaned pig would therefore be as follows:

(a) With 5 pigs raised to the litter	$ 8.69
(b) With 6 pigs raised to the litter	$ 7.24
(c) With 7 pigs raised to the litter	$ 6.21
(d) With 8 pigs raised to the litter	$ 5.43
(e) With 9 pigs raised to the litter	$ 4.83
(f) With 10 pigs raised to the litter	$ 4.35

C

When Produced by Mature Sow Kept until 4 Years Old and Producing Two Litters Each Year After Maturity (Total Six Litters).

I. Feed cost of raising the sow pig to breeding age (30 to 200 pounds)	$ 15.81

(c) Share of interest, depreciation, and insurance on buildings and general equipment	$ 2.50
(d) Risk of loss after weaning (4 percent)	$ 0.60
Total other costs	$ 5.00
Total feed and other costs of growing and finishing market pig (30 to 225 pounds),	
1. With good forage crops	$22.90
2. In dry lot	$23.82

To the above must be added the cost of the pig at weaning time. This will be determined mainly by the cost of maintaining the breeding herd and the number of pigs raised to the litter.

A

When Produced by Gilt. After Weaning Her Litter Gilt Is Fattened and Sold for Pork.

I. Feed cost of growing the sow pig to breeding age (30 to 200 pounds):	
(a) 566 pounds of concentrate @ 2½¢ per pound	$14.15
(b) One-twelfth acre of good forage @ $20 per acre	$ 1.66
II. Cost of feeding gilt from breeding to farrowing time (450 pounds of concentrates @ 2½¢ per pound)	$11.25
III. Cost of feeding sow (gilt) and nursing average litter (700 pounds of concentrates @ 2½¢ per pound)	$17.50
Total feed costs	$44.56
IV. Other costs of raising gilt and maintaining her until her litter is weaned:	
(a) Charge for original weanling sow pig (estimated)	$ 8.00
(b) Risk of loss (5 percent)	$ 1.25
(c) Vaccination and other veterinary costs	$ 1.50
(d) Interest, depreciation, and insurance on buildings and general equipment, etc.	$ 3.00
(e) Bedding	$ 0.70
(f) Boar service	$ 3.00
(g) Labor	$ 7.00
Total other costs	$24.45
Total feed and other costs of litter at weaning time	$69.01
V. Value of gilt for pork (300 pounds @ $12 per cwt. minus cost of 50-pound gain @ $10 per cwt.)	$31.00
Net cost of weaned litter by gilt	$38.01
The cost of each weaned pig would therefore be as follows:	
(a) With 4 pigs raised to the litter	$ 9.50
(b) With 5 pigs raised to the litter	$ 7.60
(c) With 6 pigs raised to the litter	$ 6.33

(d) With 7 pigs raised to the litter .... $ 5.43
(e) With 8 pigs raised to the litter .... $ 4.75

B

When Produced by Mature Sow Kept until Four Years Old and Producing Three Litters Every Two Years after Maturity (Total of Five Litters). After Weaning Her Fifth Litter She Is Fattened and Sold for Pork.

I.	Feed cost of raising the sow pig to breeding age (30 to 200 pounds)	$ 15.81
II.	Cost of feeding gilt during gestation	$ 11.25
III.	Cost of feeding sow (gilt) and nursing litter	$ 17.50
IV.	Cost of feeding open sow during two summers	$ 14.00
V.	Cost of feeding pregnant sow during three winters (1575 pounds of concentrates @ 2½¢ per pound)	$ 39.37
VI.	Cost of feeding pregnant sow during one summer gestation ..	$ 11.40
VII.	Cost of feeding sow and four nursing litters (3000 pounds of concentrates @ 2½¢ per pound)	$ 75.00
	Total feed costs	$184.33
VIII.	Other costs of raising and maintaining sow four years:	
	(a) Charge for original pig	$ 8.00
	(b) Risk of loss (1¾ percent annually)	$ 3.48
	(c) Vaccination and other veterinary costs	$ 4.00
	(d) Share of interest, depreciation, insurance on buildings and equipment for four years	$ 12.00
	(e) Five boar service fees	$ 15.00
	(f) Labor for four years	$ 30.00
	Total feed plus other costs of five litters at weaning time	$256.81
IX.	Value of sow for pork (450 pounds @ 10¢ per pound minus cost of 50-pound gain)	$ 39.50
X.	Total net cost each weaned litter produced by sow raising three litters every two years after maturity	$ 43.46
	The total cost of each weaned pig would therefore be as follows:	
	(a) With 5 pigs raised to the litter	$ 8.69
	(b) With 6 pigs raised to the litter	$ 7.24
	(c) With 7 pigs raised to the litter	$ 6.21
	(d) With 8 pigs raised to the litter	$ 5.43
	(e) With 9 pigs raised to the litter	$ 4.83
	(f) With 10 pigs raised to the litter	$ 4.35

C

When Produced by Mature Sow Kept until 4 Years Old and Producing Two Litters Each Year After Maturity (Total Six Litters).

I.	Feed cost of raising the sow pig to breeding age (30 to 200 pounds)	$ 15.81

II. Cost of feeding gilt during gestation	$ 11.25
III. Cost of feeding sow (gilt) and nursing litter	$ 17.50
IV. Cost of feeding open yearling sow during one summer	$ 7.00
V. Cost of feeding pregnant sow two summers	$ 22.80
VI. Cost of feeding pregnant sow during three winters' gestations	$ 39.37
VII. Cost of feeding sow and five nursing litters	$ 93.75
Total feed costs	$207.48
VIII. Other costs of raising and maintaining sow four years:	
(a) Charge for original pig	$ 8.00
(b) Risk of loss (1⅞ percent annually)	$ 3.73
(c) Charge for vaccination and other veterinary costs	$ 4.50
(d) Interest, depreciation, and insurance on buildings and general equipment	$ 12.00
(e) Six boar service fees	$ 18.00
(f) Labor for four years	$ 35.00
Total feed and other costs of six weaned litters	$288.71
IX. Value of sow for pork (450 pounds @ 10¢ per pound minus cost of 50-pound gain)	$ 39.50
X. Total net cost each weaned litter	$ 41.53
The total cost of each weaned pig would therefore be as follows:	
(a) With 5 pigs raised to the litter	$ 8.31
(b) With 6 pigs raised to the litter	$ 6.92
(c) With 7 pigs raised to the litter	$ 5.93
(d) With 8 pigs raised to the litter	$ 5.19
(e) With 9 pigs raised to the litter	$ 4.61
(f) With 10 pigs raised to the litter	$ 4.15

The cost of producing a 30-pound weanling pig in the three plans of breeding reviewed, based on a standard feed charge of 2½ cents a pound for concentrates and other charges estimated on the same price plane, are as shown in Table 159.

Table 159. Cost of Individual Pig at Weaning Time

System of Management	*Number of Pigs Raised to the Litter* 4	5	6	7	8	9	10
A. When produced by gilts only	$9.50	$7.60	$6.33	$5.43	$4.75		
B. When produced by sows kept until four years old, five litters		$8.69	$7.24	$6.21	$5.43	$4.83	$4.35
C. When produced by sows kept until four years old, six litters		$8.31	$6.92	$5.93	$5.19	$4.61	$4.15

Combining now the cost of the individual pig at weaning time with the cost of growing and fattening for market (30 to 225 pounds), the entire cost of the finished 225-pound pig will be as shown in Table 160.

Table 160. Showing Entire Cost of Finished 225-pound Market Pig

System of Management	*Number of Pigs Raised to the Litter* 4	5	6	7	8	9	10
A. When produced by gilts only	$32.40 or $14.40 per cwt.	$30.50 or $13.55 per cwt.	$29.23 or $12.99 per cwt.	$28.33 or $12.59 per cwt.	$27.60 or $12.29 per cwt.		
B. When produced by sows kept until 4 years old, five litters		$31.59 or $14.04 per cwt.	$30.12 or $13.38 per cwt.	$29.11 or $12.93 per cwt.	$28.33 or $12.59 per cwt.	$27.73 or $12.32 per cwt.	$27.25 or $12 11 per cwt.
C. When produced by sows kept until 4 years old, six litters		$31.21 or $13.87 per cwt.	$29.82 or $13.25 per cwt.	$28.83 or $12.81 per cwt.	$28.09 or $12.48 per cwt.	$27.51 or $12.22 per cwt.	$27 05 or $12.02 per cwt.

These costs, in round numbers, were distributed as follows: for feed, 76 percent; for labor, 7 percent; and for other costs, 17 percent.

Of the total costs, 80 percent was required in growing and fattening the pigs from weaning to market time, and 20 percent for maintenance of the breeding herd and raising the pigs to weaning age. As noted previously, as the weight at which the pigs are marketed increases, the importance of the cost of maintaining the breeding herd in relation to the total costs decreases.

BUDGETING THE FEED SUPPLY

If the data presented in the earlier pages of this chapter are reassembled and the concentrates expressed in terms of corn and tankage, the information can be readily used as a basis for estimating the feed requirements for the different seasons of the year, as well as for the different classes of hogs. This has been done below, assuming gilts to have been used exclusively for the production of the pig crop.

I. Feed required for each market pig
  (a) Spring pig with forage:
    (1) From weaning to market time (30 to 225 pounds) = 11.5 bushels of corn or equivalent + 66 pounds of 60 percent tankage or equivalent + 1/15 acre of good forage + 3 pounds simple mineral mixture.
    (2) Fed to nursing pig in creep = 16 pounds corn or equivalent + 3½ pounds tankage or equivalent.

(3) Simple mineral mixture = 3 to 8 pounds depending on character of protein concentrate.

(b) Fall pig:

(1) From weaning to market time (30 to 225 pounds) = 12 bushels corn or equivalent + 75 pounds tankage or equivalent + 75 pounds legume hay.

(2) Simple mineral mixture = 6 to 12 pounds.

II. Feed required to raise gilt (30 to 200 pounds) = 9 bushels of corn or equivalent + 50 pounds tankage or equivalent + 1/12 acre good forage + 3 to 5 pounds simple mineral mixture.

III. Feed required by each bred gilt during winter gestation period (200 to 300 pounds) = 7 bushels of corn + 30 pounds tankage or equivalent + 30 pounds legume hay + 5 pounds simple mineral mixture.

IV. Feed required for each sow (gilt) during nursing period of 8 weeks = 9 bushels of corn or equivalent + 60 pounds tankage or equivalent + 30 pounds legume bay + 7 pounds simple mineral mixture.

V. Feed required to grow and maintain spring boar pig one year

(a) From weaning to breeding season = 11 bushels corn or equivalent + 66 pounds tankage or equivalent + 1/12 acre good forage + 3 pounds simple mineral mixture.

(b) For boar pig during winter = 8 bushels of corn or equivalent + 45 pounds tankage or equivalent + 50 pounds legume hay + 5 pounds simple mineral mixture.

When summarized, the supplies of the feeds commonly fed required for the production of 100 225-pound market pigs, about two-thirds spring-farrowed and one-third fall farrowed, and assuming seven pigs raised to the litter, would be in round numbers as follows:

Corn or equivalent	1400 bushels
Oats	100 bushels
Tankage or equivalent	2 tons
Soybean oil meal or equivalent	2 tons
Shorts and bran	½ ton
Legume hay	1½ tons
Forage pasture	6 acres
Minerals	660 pounds

These figures are based on the results secured under good feeding conditions and on the assumption that seven pigs are raised to the litter. All the oats included in the budget were fed the pregnant sows, in an amount to make up one-fourth to one-third of the ration. The amount of middlings or shorts and bran fed is regarded as the minimum required for best results. All of that fed here was given the sows during the farrowing and nursing periods. A fairly liberal allowance of legume hay was included chiefly because of its protective value against vitamin-deficiency ailments.

XVII *Marketing*

Sixty-four percent of the nation's hog production during the 5-year period 1943 to 1947, averaging more than 83 million head annually, was slaughtered in the 277 packing plants operating under Federal inspection; 16 percent of the production was farm-slaughtered, and 20 percent killed in wholesale and retail plants not under Federal inspection.[1] Of the 53 million head killed under Federal inspection, 87 percent consisted of barrows and gilts, 12.3 percent of sows, and 0.6 percent of boars and stags.

MARKETING

Marketing channels used. The various routes traveled by market hogs from farmers in the swine-producing areas of 14 states to slaughtering plants and other markets in 1940 are shown graphically in Fig. 62.[2]

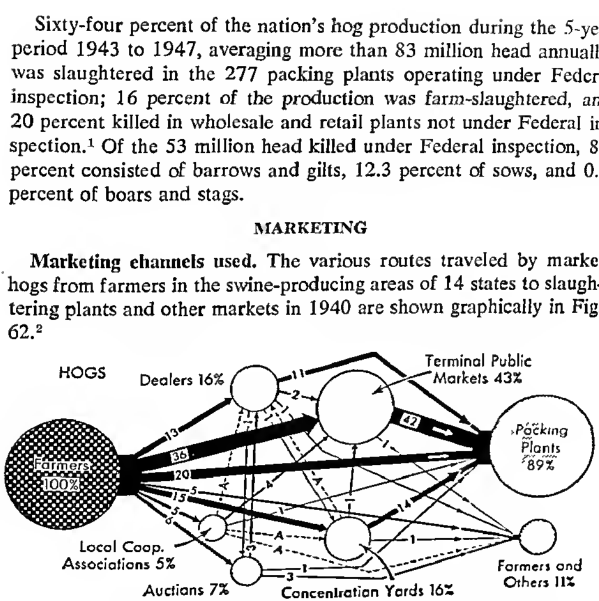


Fig. 62. Channels through which hogs are moved from farmers to packers (*Corn Belt Marketing Research Committee, Marketing Livestock in the Corn Belt Region, Bul. 365, S. Dak. Exp. Sta., 1942*).

[1] *Agri. Statistics*, U.S.D.A., 1948 and *Livestock Market News*, Production and Marketing Administration, U.S.D.A., C.S-38, 1949.

[2] Corn Belt Livestock Marketing Research Committee. Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta., Bul. 365, 1942.

The relative importance of these channels as marketing routes is indicated by the percentages of the hogs using them. Of the hogs received by the packer, 53 percent came through the terminal markets, 22 percent came direct from the farmer, and most of the remainder direct from dealers and concentration yards. Of the relatively small number of hogs handled by local cooperative associations, about four-fifths reached the packer through the terminal markets and one-fifth direct. Most of those sold at auction were handled by dealers who generally, in turn, sold directly to the packer. The type of marketing employed varied considerably, however, in the different areas covered in the study.

Type of market related to number sold. That the type of market used by the farmer is influenced by the number of hogs sold is indicated by the figures in Table 161.

Table 161. Relationship Between the Number of Slaughter Hogs Sold by Farmers in 14 States and the Type of Market Used, 1940 [3]

Number Sold / *Where Sold*	*Less than 10 Head*	*10 to 59 Head*	*60 Head and Over*
	%	%	%
Terminal public markets	29.0	33.5	40.5
Packing plants	21.4	22.5	22.1
Dealers or truck buyers	15.5	15.9	11.6
Auctions or sale barns	8.8	5.2	3.7
Concentration yards or local markets	12.2	14.0	15.9
Local cooperative associations	6.0	7.2	5.7
Farmers or others	7.1	1.7	0.5

These figures show that farmers when selling small lots are more likely to patronize local markets, such as auctions, local dealers, and other farmers than those located at more distant points. Shipments of large volume, on the other hand, are more generally sent to the terminal markets or concentration points.

The number of hogs sold per farm in this area averaged 45 head, and the average size of the lots numbered 14. Thus each farm made more than three sales during the year. One-fourth of the farmers had shipments numbering five head or less, but these represented only 6 percent of the total number of hogs sold. One-eighth of the farmers disposed of their hogs in lots of 26 or more, which comprised one-third of the total number marketed. More than 50 percent of the hogs

[3] Corn Belt Livestock Marketing Research Committee, Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta. Bul. 365, 1942.

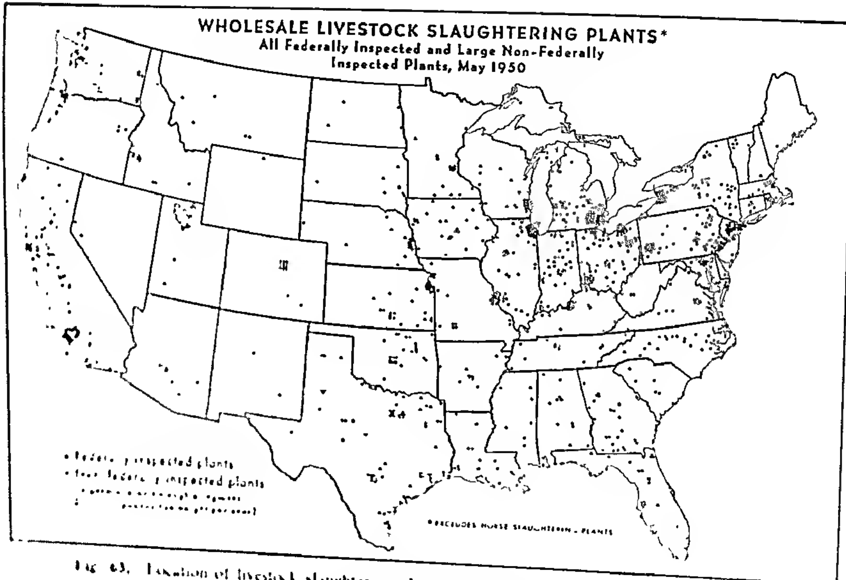


Fig. 63. Location of livestock slaughtering plants in the United States (courtesy U.S.D.A. Bureau of Agr. Economics)

sold in Indiana and more than 40 percent of those in Iowa were disposed of in lots exceeding 26. In Michigan, only 10 percent were sold in lots of this size.

Transportation by truck and rail. The Corn Belt Livestock Marketing Research Committee [4] reports that it is impossible to say what percentage of the hogs is moved from farm to slaughterer by truck as compared with rail. Some move only by truck, others only by rail, and most both by rail and truck. The distance may be short or long, and the number large or small. They may move from farm direct to packer by truck; from farm to railroad shipping point, concentration yard, cooperative or dealer's assembly point by truck, and thence to final destination either by truck or rail. In some, the movement is continuous, in others it is broken one or more times. Often a break in the movement involves a change in ownership as well as in the type of transportation. Increased mileage of hard-surfaced roads, and larger and better designed trucks have resulted in increasing reliance on the truck as a means of transportation in recent years.

The types of transportation used in the various steps involved in marketing hogs are shown in Table 162.

Table 162. Percentage of Hogs Transported by Truck and Rail, 1940 [5]

Origin and Destination of Shipments	*Truck*	*Rail*
	%	%
From farm direct to packer	87.3	12.7
From farm to auctions	95.6	4.4
From farm to dealers, local coops., concentration yards, or retail slaughterers	100.0	0.0
From dealer to packer	73.4	26.6
From coop. assembly point to packer	47.4	52.6
From concentration point to packer	21.2	78.8
From auction to packer	84.8	15.2

Of the hogs received at the 60 or more public or terminal markets of the country since 1933, 66 percent was delivered by truck (drive-ins) and 34 percent by rail (unweighted averages).[6] In 1948 truck deliveries represented 73.9 percent of the total. At the numerous, relatively small interior markets of the Corn Belt, truck deliveries constitute a larger proportion than at the larger markets or at those situated

[4] Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta. Bul. 365, 1942.
[5] Corn Belt Livestock Marketing Research Committee, Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta. Bul. 365, 1942.
[6] *Livestock Market News,* 1947 and 1948, Prod. and Mark. Adm., U.S.D.A.

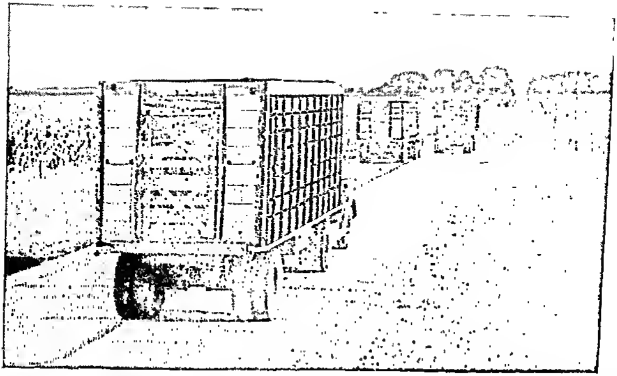


Fig. 64. Double-deckers on the way to market. Modern trucks and paved highways combine to furnish quick, convenient, and efficient transportation *(courtesy, Ind. Exp. Sta., photo by Allen).*

in distant consuming areas. At a number of these, practically 100 percent of the hogs during the past decade has come in by truck.

Transportation costs. The largest part of the marketing costs is represented by transportation charges. Carrier rates vary, of course, with the distance and size of the shipment. In Table 163 are given the freight rates on shipments of both live hogs and meat products between strategic markets of the country for the year 1950.

Studies by Lambrecht and Garey of the Nebraska Station [7] of rail and truck shipments of live hogs to the Omaha market from 1930 to 1935 showed the truck rates to be 24 percent higher than the rates for rail shipments for comparable distances from 50 to 400 miles. Compared with rates during this depression period, present costs of transportation represent an increase of about 100 percent.

Rates for both truck and rail service have increased considerably in recent years, but truck rates remain somewhat higher than rail rates, especially for the longer distances. Rail shipments, however, require trucking service from farm to rail loading point. When this expense is added to the cost by rail, the total transportation charges by the two methods do not differ greatly. Competition also may be expected to have an equalizing effect.

[7] Geo. H. Lambrecht and L. F. Garey, Bul. [illegible]

Table 163. Freight Rates on Live Hogs and Meat Products, 1950, in Dollars per Hundredweight

From	To	Live Hogs Single Deck	Live Hogs Double Deck	Fresh Meat	Cured Meat and Packing House Products	Authority
Chicago	New York	1.06	0.91	1.43	0.97	U.S.D.A., Produc-
Omaha	New York	...	1.45	2.05	1.45	tion and Marketing
Chicago	San Francisco	2.22	1.95	2.88	2.40	Administration,
Omaha	San Francisco	1.83	1.60	2.42	2.02	Chas. B. Bowling,
Kansas City	San Francisco	1.83	1.60	2.52	2.11	Chief Transp. Rates
Omaha	Chicago	0.75	0.65	0.65	0.65	Chicago, Rock
E. St. Louis	Chicago	0.56	0.47	0.51	0.42	Island and Pacific
S. St. Paul	Chicago	0.71	0.61	0.52	0.47	R.R. Co., W. J.
Omaha	Los Angeles	1.77	1.53	2.42	2.02	Stem, Chief of
Omaha	San Francisco	1.83	1.60	2.42	2.02	Traffic Bu.
Chicago	Baltimore	1.00	0.87	1.38	...	Chicago, Burling-
Chicago	Boston	1.06	0.91	1.43	...	ton and Quincy
Indianapolis	Boston	0.97	0.86	1.33	...	R.R. Co., G. A.
Indianapolis	Chicago	0.29	0.25	0.34	...	Hoffelder, Frt.
Cincinnati	Baltimore	0.87	0.75	1.28	...	Traffic Mgr.

Marketing costs. Bjorka of the Bureau of Agricultural Economics [8] estimated the average cost of marketing hogs in 1939, not including transportation costs, to be as follows for the different types of market:

Dealers	15¢ per cwt.
Local cooperative associations	15¢ per cwt.
Concentration yards	11¢ per cwt.
Auctions	22¢ per cwt.
Public markets	24¢ per cwt.
Direct to packer	00¢ per cwt.
Adjusted average	19¢ per cwt.

Terminal market charges. For handling and selling hogs on the Chicago terminal market, the charges for the year 1950 were as follows: [9]

Yardage:

By rail	25¢ per head
By truck	29¢ per head

[8] Knute Bjorka, U.S.D.A., Tech. Bul. 932, 1947.

[9] Information, courtesy D. L. Swanson, Manager, Chicago Producers' Commission Association, Nov., 1950.

Feed (corn, $2.20 per bushel)	12¢ per head
Commission:	
First 10 head	37¢ per head
Next 15 head	32¢ per head
Each head over 25	27¢ per head
Fire insurance, one-fifth cent each head with maximum charge of 7¢ per owner in any truck load	0.2¢ per head
Meat Board, one-third cent each (for promotion and advertising by National Live Stock and Meat Board)	0.33¢ per head
Approximate total	75¢ per head

Assuming an average market weight of 240 pounds, the cost approximates 31 cents per hundredweight. Charges at the different terminal markets are fairly uniform.

Shrink and other losses in transit. What amounts to a marketing charge is represented by shrinkage or loss of weight in transit, death and cripple losses, as well as losses due to shipping bruised and damaged meat. Although these losses are not all assumed directly, or are apparent to the farmer when he sells, the price he receives at any of the marketing points is less by the amount of these losses, or the risk of them, assumed by the buyer.

Loss of weight in transit is due to tissue and excretory shrinkage. Excretory shrinkage represents the loss of weight due to the normal elimination of excreta, and presumably does not mean any loss of carcass weight. Tissue shrinkage, on the other hand, involves a loss in the weight of the meat or carcass. Just how much of this latter is water and subject to recovery later after resting, feeding, and watering is not known.

The amount of shrinkage is influenced by the time in transit or distance traveled, the weight of the hogs, the season of the year, and the amount of fill taken before final weighing. Attention given to matters of feeding, loading, care, and handling in route also is responsible for much of the variations in shrink observed in similar shipments. Shrinkage increases as the distance traveled or time between weights increases, but the rate of loss decreases as the time or distance increases. Light hogs shrink more in proportion to live weight than heavy hogs under like conditions and for comparable distances, although they recover the loss more promptly than do the heavy hogs. Wiley's data for rail shipments, however, showed less shrinkage per hundredweight for light than for heavy hogs. Shipments in winter

shrink slightly less than summer shipments. Tissue and excretory shrinkage each is affected in the same manner by these factors.[10]

"Fill." The amount of fill taken on at destination point prior to weighing is one of the important factors affecting excretory shrinkage. Armour's Livestock Bureau [11] reported from data based on the weights of more than 750,000 hogs in 1927 and 1928 that this fill amounted to an average of 5.5 pounds, or 2.5 percent of the live weight. But excessive fill, beyond that which is dictated by humanitarian motives, although adding to the selling weight, contributes nothing to the carcass value, reduces the dressing yield, and lowers the selling price. The packer buyer, equipped as he is with experience and the data on the yield of previous purchases, may be expected to make due allowance for the extra weight in the price he bids. The practice is an economic waste and on the whole does not profit the producer.

The practice of feeding and watering before weighing to the buyer differs at the different markets, as shown by the studies of the Corn Belt Livestock Marketing Research Committee which are summarized in Table 164.

Table 164. Extent to Which Hogs were Fed and Watered at Different Types of Markets, 1940 [12]

	No Feed or Water	*Water Only*	*Both Feed and Water*
	%	%	%
Auctions	28.8	46.6	24.6
Concentration yards	82.4	10.5	7.1
Direct to packer	92.2	7.2	0.6
Local coop. associations	92.7	6.9	0.4

For hogs sold at the public or terminal markets, the practice of feeding and watering before weighing has been the common one. In recent years, however, an increasing proportion of these deliveries have been offered for sale without filling, especially in the case of those coming in by truck.[13]

[10] Knute Bjorka, U.S.D.A., Tech. Bul. 621, 1938; James R. Wiley, Ind. Agr. Exp. Sta., Bul. 337, 1930 and Bul. 358, 1932.

[11] *Monthly Letter to Animal Husbandmen*, Aug., 1929.

[12] Corn Belt Livestock Marketing Research Committee. Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta., Bul. 365, 1942.

[13] Austin A. Dowell and Knute Bjorka, *Livestock Marketing*. McGraw-Hill Book Company, Inc., New York, 1941.

Amount of shrinkage loss. Wiley of the Indiana Station[14] reported an average shrinkage of 2.13 percent of the live weight for rail shipments consigned by the Indianapolis Producers' Commission Association from 1925 to 1929, initial weights being taken at the rail loading points. Any loss of weight between farm and loading point was not determined. Bjorka of the Bureau of Agricultural Economics[15] computed the shrinkage of hogs weighing from 200 to 320 pounds and in transit 7 to 12 hours from data supplied by 49 packing plants for rail shipments received by them from 365 concentration points and 34 public markets. Shipments from the concentration points had a shrink of 4.82 percent; those from the public markets shrank 3.89 percent. Apparently, these hogs had not been fed and watered before weighing at destination.

Truck and rail shrinkage compared. Ashby of the Illinois Station[16] compared the shrinkage of truck and rail shipments for hogs coming from the same farms and loaded out at practically the same time. Both the short truck and longer rail shipments were given their regular feed before weighing out at the farm. However, the trucked hogs were not fed or watered at the market, as is customary for short hauls to interior markets, whereas the rail consignments were fed and watered at the market, which is the common practice at the public or terminal markets. The results are shown in Table 165.

Table 165. Shrinkage on Truck and Rail Hogs from the Same Farms
(Truck hogs not fed or watered at the market, rail hogs fed and watered at the market)

fed and watered at the same time in the same alley, and were sold and weighed at the same time. The test is unique since all conditions were comparable.

Table 166. Shrinkage of Truck and Rail Hogs Handled under the Same Conditions

Transportation	*Average Distance*	*Number of Consignments*	*Number of Hogs*	*Average Farm Weight of Hogs*	*Average Shrink per Hog*	*Weighted Average Shrink*
	miles			lb.	lb.	lb. per cwt.
Truck	130	5	65	250	3.00	1.20
Rail	130	5	286	267	3.30	1.24

The results show no significant difference in shrinkage between these truck and rail shipments handled under like conditions.

Because of the effect of other factors, it is difficult to compare rail with truck shrinkage. The data available indicate, however, that when handled under comparable conditions, the difference is not significant, although there is a suggestion in the data that trucked hogs lose more on long hauls. Considering the improvements which have been made in truck design in recent years and the increased mileage of hard-surfaced roads, there are those who doubt if this advantage in rail transportation can now be admitted. With this, however, it should be stated that stock cars and loading facilities have been much improved during the same period by the railroads.

Feeding prior to loading. Robison of the Ohio Station [18] compared the effect of feeding at the farm the morning before loading out with that of withholding the morning feed for hogs trucked 1 to 2 miles and then transported by rail a distance of 135 miles. At the market they were fed and watered before the final selling weights were taken. There were 138 hogs in each group with average weights of about 220 pounds.

The hogs which were not given their morning feed shrank less in transit and took a heavier fill at the market than those that were fed; but this advantage was more than offset by the loss of weight suffered by the hogs that were fasted before weighing out. Based on the weights taken the afternoon of the day before weighing out, those given their morning feed lost 4.6 pounds per head, while those not fed lost 6.4 pounds.

[18] W. L. Robison, Bul. 497, 1932.

In further tests Ashby showed that hogs, given a normal or full feed at the farm before loading out by truck, shrank less than those trucked like distances (0 to 55 miles) which received a limited feed at the farm by the difference between 1.50 and 1.72 percent. These hogs were not fed or watered at the market. For hogs trucked like distances that were given feed and water before weighing at the market, there was no difference in shrink due to the feeding treatment at the farm

It would appear from these two tests that most of the farm fill may be retained for short distances when the hogs are handled carefully. The author, however, cautioned against interpreting the results as a general recommendation for full-feeding at the farm for all truck or rail shipments. Especially in hot weather, heavy feeding just prior to loading is bad practice.

Data assembled by the National Livestock Loss Prevention Board of death and cripple losses occurring in rail and truck shipments to the five river markets, Kansas City, St. Joseph, Omaha, Sioux City, and St. Paul in recent years are shown in Table 167.

Table 167. Death and Cripple Losses of Hogs Arriving by Rail and Truck at the Five River Markets, 1936 to 1949 [20]

	Number Dead per 1000		*Number Crippled per 1000*	
Year	*Rail*	*Truck*	*Rail*	*Truck*
1936	0.74	0.95	1.61	1.38
1940	0.43	1.01	2.41	2.22
1944	0.67	1.56	1.60	1.82
1948	0.98	1.82	1.03	3.16
1949	0.67	1.72	2.66	3.44

Death losses by truck in this study were twice as great as those by rail. The number of cripples by truck was one and one-third times the number by rail. These figures, based on the marketing annually of 1,892,000 hogs by rail and 7,451,000 by truck, supply no evidence that death and cripple losses have been reduced in recent years; they indicate rather an increase.

Considering the death and cripple losses shown by the National Livestock Loss Prevention Board data, it is calculated, assuming a loss of 40 dollars for the dead and 10 dollars for the crippled (hogs selling at $12.75 per hundred weight), that together they represent a loss of 7.4 cents a head for all market hogs (5.1 cents for the dead, and 2.3 cents for the cripples).

Bruises are costly. The economic loss which results from bruising is greater than the combined death and cripple losses. Bruising results in damaged meat, the loss being determined by the weight of the bruised trim and the reduced value of the cut.

Based on weekly tests made by Wilson and Company of Chicago of lots of good to choice butcher hogs selected at random from rail and truck deliveries from March 1946 to January 1950, 34 percent were found to be bruised more or less.[21] Observation of the carcasses following slaughter revealed the following proportion of the wholesale cuts to have been damaged: 19 percent of the hams; 10 percent of the fat backs; 0.2 percent of the loins; 4.6 percent of the bellies; and 5

[20] National Livestock Loss Prevention Board, An. Rpt., 1949, H. R. Smith, Gen. Mgr.

[21] *Reported by the National Livestock Loss Prevention Board, An. Rpt., 1950.*

percent of the shoulders. Of the hogs bruised, the loss per head amounted to an average of 39.8 cents. Applied to the entire number slaughtered, it represented an average loss of 13.5 cents per head—6.2 cents for trim and 7.3 cents loss due to degrading. The average loss on the rail shipments was 14.3 cents per head, and on truck deliveries 12.9 cents; for comparable distances, however, the loss on the trucked hogs was slightly greater than on those shipped by rail.

These investigators judged that 62 percent of the bruises were man-inflicted, and 38 percent the result of accidents. Forty-two percent apparently were caused by cane, whip, or club; 20 percent by kicking or prodding; 15 percent by crowding and/or trampling; 12 percent by fork, nail, or other puncture; 1.7 percent by "spreaders" (slippery footing); and 9.3 percent by other causes.

Estimated total loss from death, cripples, and bruises. Combining the losses due to death, crippling, and bruises, we have the following estimates for all hogs marketed:

From death	5.1 cents per head
From crippling	2.3 cents per head
From bruises	13.5 cents per head
From all three	20.9 cents per head

or approximately 9 cents per hundredweight. Farmers generally do not realize the magnitude of these losses.

Precautions which reduce losses. To reduce to a minimum losses due to shrinkage, death, crippling, and bruises, the following recommendations with respect to feeding and handling should be observed:

For hogs trucked short distances to market where they are sold without feeding or watering, normal feeding at the farm before loading out would seem to be advisable, especially when the weather is cool and they are handled and driven carefully.

For distances greater than about 75 miles, however, especially when the stops en route are numerous, the weather hot, or if they are not handled carefully, a limited feed at the farm before loading will reduce the danger of losses without sacrificing a significant amount of weight.

Trucked hogs en route 6 or 8 hours to public or terminal markets where they are sold after feeding and watering usually will take a better fill at destination if they are not loaded full of feed at the farm, and risk from other losses will be reduced.

For rail shipments the same rules in general should be observed as for the longer truck hauls. Shipments by rail are required by law, for

humanitarian reasons, to be unloaded, fed, and watered at the end of each 28-hour period while in transit, but the time can be extended to 36 hours on the request of the shipper or owner.

Overloading is one of the most common causes of loss in hot weather.[22] Studies show losses to increase when loading a 36-foot car heavier than 18,000 pounds in cold or cool weather, or 17,000 pounds in warm or hot weather (or for a 40-foot car, more than 20,000 pounds in cold or cool weather or 19,000 pounds in warm or hot weather). Underloading also should be avoided.

For trucked hogs the National Livestock Loss Prevention Board [23] makes the recommendations with respect to loadings as given in Table 168.

Table 168. Number of Hogs per Truck

Length	Weight of Hogs 100	150	200	250	300
	lb.	lb.	lb.	lb.	lb.
13-ft. truck	43	33	26	23	20
16-ft. truck	58	44	35	30	26
20-ft. truck	70	54	42	36	32
24-ft. truck	86	65	52	45	39

The following rules or suggestions, arrived at after long study and observation, have been promulgated by the National Livestock Loss Prevention Board as a part of its campaign of education to help reduce the costly waste in marketing hogs:

1. Remove projecting nails, splinters, and broken boards in feed racks and fences.
2. Keep feed lots free from old machinery and objects that may bruise.
3. Do not feed grain heavily just prior to loading.
4. Bed with sand, free from stones, to prevent slipping.
5. Cover sand with straw in cold weather, but no straw in hot weather.
6. Wet sand bedding in summer before loading and while en route. Drench when necessary.
7. Remove protruding nails, bolts, or any sharp objects in truck or car.
8. Use loading chutes, not too steep.

[22] James R. Wiley, Ind. Exp. Sta. Bul. 318, 1927.
[23] An. Rpt., 1949, H. R. Smith, Gen. Mgr.

9. Load slowly to prevent crowding against sharp corners, and to avoid excitement.

10. Use canvas slappers instead of clubs or canes.

11. Do not overload.

12. Always partition mixed loads.

13. Partition packing sows from light weight butchers.

14. Bull board should be in position and secure before car door is closed.

15. Provide covers for trucks to protect from sun in summer and cold in winter.

16. Drive carefully. Slow down on sharp turns and avoid sudden stops.

17. Back truck slowly and squarely against unloading dock.

18. Unload slowly. Don't drop animals from upper to lower deck; use cleated inclines.

Mitchell of the Indiana Station [24] emphasizes, in addition to these, the importance of doing any necessary sorting of the hogs the day before they are loaded out, and secondly, of getting the hogs to distant markets early enough to allow a rest of several hours before feeding.

CHOOSING A MARKET

A variety of markets available. In no country is there such a wide variety of markets and marketing agencies available to the farmer for the disposal of his hogs as is found in this country (see Table 161). He may sell directly to a local buyer, an interior packer, or at a cooperatively or packer-owned concentration yard at a price agreed on before delivery; or he may ship to a terminal market or consign to a shipping association and take whatever price they command at the destination.

This variety of market outlets and methods of selling may be considered an advantage by the farmer since it provides an opportunity to choose between competitive markets. At the same time, however, an intelligent choice is often difficult because of the complication of numbers and a lack of information on transportation and marketing costs, as well as of supplies and prices at the larger markets.

There is no one best market or system of marketing hogs. There may, however, be one system better adapted than any other to a given area. The wide distribution of the supplies, the variation in the size of lots sold, and the varied distances to consuming centers impose con-

[24] M. Paul Mitchell, *Economic and Marketing Information*, A-g, 1950.

ditions which have largely been responsible for the wide variety now in use.

Direct marketing. A subject which caused rather heated controversy among farmers and the various marketing agencies following World War I was that of direct marketing. In this system the hogs pass from the farmer to the packer without the employment of a commission or selling agent located at the terminal markets. Such sales usually are made direct to a local packer or to the agent or buyer of a Mid-west or Eastern packer at a packer-owned yard or concentration point located in the producing area. A rather marked increase in direct buying by packers occurred during the period from 1920 to 1930; since then it has been less rapid. The number of hogs bought direct by packers in 1940 represented 53 percent of their entire purchases.[25] Shepherd of the Iowa Station [26] reported that in 1937 two-thirds of the hogs sold in Canada were marketed direct.

Conditions which have favored direct buying. Students of livestock-marketing problems explain this method of buying on the part of the large packers as being the result of economic changes affecting the industry; principally, to the growing strength of the small interior packers situated in close proximity to the supply, and to the generally lower freight rates on hog products than on live hogs from points west of the Mississippi River to points east. These have given to the interior packers competitive advantages which have threatened the position of the large packers located at the terminal markets. In order to secure the volume of supplies necessary to keep their plants profitably employed and to hold their trade, especially during periods of acute shortage in hog numbers, the public-market packers found it in their interests to go to the country for direct purchases. Railroad concentration privileges with respect to freight rates also have facilitated this change.[27]

Have the farmers' interests been adversely affected by direct marketing? Opponents of direct marketing claim that the increased number of local markets in the producing areas and the resulting reduction in the proportion of the hogs sold on the open large terminal markets, a development which has been coincident with direct mar-

[25] Corn Belt Livestock Marketing Research Com., Report prepared by Knute Bjorka, S. Dak. Agr. Exp. Sta., Bul. 365, 1942.

[26] Geoffrey Shepherd, Bul. 353, 1937.

[27] Concentration privileges west of the Mississippi permit changes in the make-up and ownership of hogs at points between origin and destination, and a through rate from original loading point.

keting, has tended to depress the general level of hog prices. They believe that the pre-ownership of a third or more of the arrivals gives to the packer an unfair bargaining power in the purchase of hogs on the open market; and that hogs bought directly generally are of a better grade and contain fewer culls than are represented in the supplies available at the terminal market, thus creating the opportunity to lower the price bid on the better grades at the interior buying points. Considerable evidence or testimony in support of these claims has been furnished by the extensive studies of Ashby of the Illinois Station.[28]

In 1933 the U.S. Department of Agriculture, in response to requests from those opposed to the practice, inaugurated an intensive study of direct marketing. This was undertaken by the Bureau of Agricultural Economics with the cooperation of State Experiment Station workers, the results being published in 1935 under the title *The Direct Marketing of Hogs*.[29] The conclusions based on the results of this exhaustive study are briefly summarized below.

1. Although hogs that are sold directly may pass through several hands before reaching the packer, the investigators found that the total handling and selling costs were less than when sold through commission agents at the public market, and the net return to the producer somewhat greater.

2. The study supplied no important evidence that direct marketing had exerted a depressing effect on the price of hogs. The decline in hog prices following 1926 was due to other causes, namely, to the markedly reduced buying power of the consumer and the restricted foreign demand for our pork products.

3. There did not appear to be any evidence that direct buying had restricted competition among packers or that it enabled them to exact a wider margin for their services. Changes in the spread between the farm price of hogs and the price of wholesale pork were found to be caused rather by higher wages and rents, higher freight rates, and more expensive packaging.

4. They found no justification for the claim that other markets follow Chicago, or that Chicago sets the prices for other markets, although, because of its size and its geographical position, it may be expected to have more influence on intermarket prices than any other market.

[28] R. C. Ashby, Bul. 408, *Local Livestock Markets in Relation to Corn Belt Hog Marketing*, 1934.
[29] U.S.D.A. Misc. Pub. No. 222, 1935.

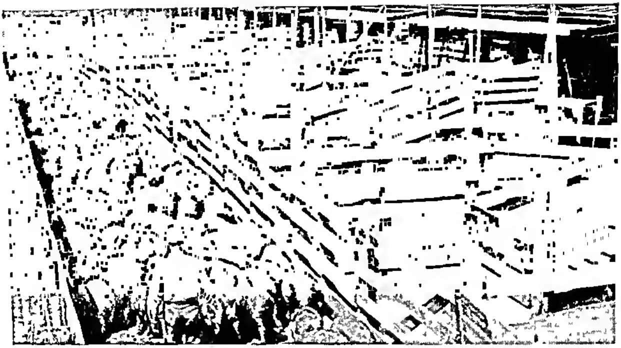


Fig. 66. A small part of the nation's pork supply on its way to the consumer *(photo by Allen).*

Price changes from day to day were less frequent on interior than on public markets; and prices paid at interior packing plants in southern Minnesota and Iowa were found to move together from day to day more closely than either with Chicago or Sioux City.

5. The data presented showed that there were some but no significant differences between the quality and grade of hogs purchased by packers directly and those bought at the terminal market from commission agents representing the producers. Nearly 200,000 hogs representing packer purchases by the two methods were classified by qualified graders as follows:

The percentage distribution of the grades of hogs consigned for sale was as follows:

	Percent
Choice	19.3
Good	41.7
Medium	33.8
Cull	5.2

For hogs bought directly the distribution was:

	Percent
Choice	15.5
Good	40.9
Medium	39.9
Cull	3.7

Although there was a smaller proportion of culls among the hogs bought directly, there were, on the other hand, fewer hogs of the choice and good grades. It was concluded that the distribution supplied no evidence that the packer would be able to buy the better grades at interior points at the prices paid for lower grades on the terminal or public market.

Recommendations for improving market services. The studies of direct marketing, which have just been reviewed, disclosed that certain of the market practices were in need of correction or improvement. It was recommended that the use of the "board" price with a variable "add" [30] at direct-buying points be replaced by one that makes known the range of prices being offered and paid for the different grades; that the practice of "filling" hogs before selling be discontinued; that sows and stags be bought on their merits without docking; that provision be made for official supervision of scales at interior points; that uniform grade standards be used at all markets; and that the Federal Market News Service be extended to include all direct-marketing areas.[31]

There probably is no system of marketing altogether free from abuses or the opportunity for sharp practices. To the farmer, the best system is the one which will ensure him honest weights and a fair price, considering the quality of his offering, the demand, and the price differentials at other markets.[32] There are those still who maintain that the farmers' best interests are served, especially when large lots are sold, by consigning to a commission agent in whom experience has given him confidence rather than by selling direct to the packer. The experience of the agent in the matter of sorting mixed lots, in the supervision of their care and feeding on arrival at the yards, and in bargaining with packer and order buyers which must precede their

[30] The "board" or "card" prices are the announced base or minimum prices which will be paid for hogs of specified weights and grades and are used by operators of concentration yards and packers who buy directly in southern Minnesota and Iowa. The "add" represents the amount above the board price which is paid. The amount of the "add," which is not published, is determined chiefly by the shrink or distance hauled, the quality of the hogs, and competition. It may vary from 10 to 55 cents per hundredweight.

[31] U.S.D.A. Misc. Pub. No. 222, 1935.

[32] Practically all the important markets in the country now are "posted." Posted markets include all those under Federal supervision, as established by the Live Stock Marketing Act of 1921 as amended (Information by M. Paul Mitchell, Ind. Exp. Sta., 1950). To qualify for supervision a market must (a) have 20,000 square feet of pen area, (b) be operated for profit and in the public interest, and (c) engaged in interstate commerce. Supervision is concerned with the elimination of unfair trading practices, bonding of market agencies, the supervision of scales and methods of weighing, and with investigating and handling all complaints of buyer or seller.

sale, represent, to many, services which exceed in value the cost of the commission fee. Also, the large number of buyers at the terminal markets will ensure a wide demand outlet.

The individual farmer, although he has access to daily radio broadcasts, generally is not equipped with the market information which is necessary to judge current prices accurately or to relate them to the grade of hogs he has for sale. Also, largely because of the limited number of hogs produced, he is not in a position to keep in touch with or to take advantage of distant market outlets. Dowell and Bjorka in their book, *Marketing Livestock*,[33] express the belief that the services supplied by expertly manned large local or district cooperative associations, which emphasize the marketing rather than the shipping function, offer one of the most promising means for the solution of the individual farmer's marketing problems.

MARKET CLASSES AND GRADES

The daily run of hogs at any large market, especially in midsummer, is made up of individuals of varying ages, weights, quality, finish, and sex. In handling such a mixture, some system of classification and grading is obviously necessary in order to facilitate trade, for the accurate reporting of market prices, and for an understanding of general market conditions. It is of fundamental importance to the industry that the trade terms used be standardized and that the farmer, packer, and trader have a common understanding of their application and use; otherwise confusion results. Unfortunately, it cannot be said that uniformity of classification exists, although some progress in that direction has been brought about through the wider adoption of the Agricultural Marketing Service of the U.S. Department of Agriculture.[34]

Market hogs are classified according to their use, their kind, and their weight; and these are graded respectively, according to their quality or value. Depending on the use to which they are put, they are

[33] Austin A. Dowell, and Knute Bjorka, McGraw-Hill Book Company, Inc., New York, 1941.

[34] The Federal Market News Service of the U.S. Department of Agriculture for livestock was inaugurated in 1918. Its purpose is to collect and distribute regularly and promptly accurate and complete marketing information concerning livestock supplies, demand, and prices in all marketing areas of the country. The reports are made daily at the larger markets, with summaries covering all areas issued weekly, monthly and annually. The information is transmitted by leased wires, the four national press services, 1100 radio stations, free mail reports, and newspapers. Also a weekly report is issued on Saturday from the Des Moines office covering the supply, demand, and trend of prices for hogs sold direct at approximately 30 concentration yards and 11 packing plants in Iowa and southern Minnesota (*The Market News Services*, Reprint Misc. Pub. No. 703, and *Periodic Market Reports*, Production and Marketing Adm., U.S.D.A., 1950).

grouped into the two major divisions, Slaughter hogs and Feeders. Slaughter hogs include the following classes: Butcher hogs (barrows and gilts), Packing sows, Stags and Boars, and Pigs. Feeders include Pigs weighing from 80 to 120 pounds, and Hogs weighing from 120 up to 180 pounds.

Butcher hogs. Representing as they do about 87 percent of the total number of hogs marketed annually, butcher hogs constitute the major part of our country's pork supply. Being composed wholly of young barrows and gilts, most of which are from 5 to 8 months of age, the class also produces the weight and quality of cuts in greatest demand by the consumer.

Butcher hogs may weigh from 140 to 350 pounds or more. Because of the importance of weight as a factor affecting the price, they are grouped into weight subclasses. On most markets and in the schedule used by the Federal Market News Service these subclasses are made with 20-pound intervals up to 240 pounds, and thereafter with intervals of 30 or 40 pounds. Other designations formerly common in the trade and still used to a limited extent for heavy hogs of this class are "prime heavies," "heavy loin hogs," and "fat backs." These refer to very fat smooth heavy butcher hogs of quality weighing 300 pounds and up. The use of these terms is being discouraged.

Packing sows. This class is composed of sows which have done service in the breeding herd. They are of an age generally from 2 to 4 years, and are found on the market in largest numbers in the late summer and early fall. They constitute on the average around 12 percent of the total number of hogs marketed annually. In weight they range usually from 275 to 600 pounds. Pregnant or "piggy" sows are usually sold subject to a dock of 20 to 40 pounds. Hogs of this class produce meat of coarse quality and the cuts are generally too heavy and often too fat for the production of fresh or cured meats of standard quality.

Stags and boars. Stags and boars constitute less than 1 percent of all slaughter hogs. Stags are castrated boars and formerly were sold with a dockage of 80 pounds. Now, they sell without docking at all plants operating under Federal supervision. Boars are sold without docking. The meat, especially of old boars, is coarse in quality and very strong in flavor. Boar carcasses are not allowed in the same cooler with the other carcasses in plants having Federal inspection. Carcasses of young boars are largely used in sausage manufacture.

Slaughter pigs. Slaughter pigs, weighing as they do from less than 30 to 120 pounds, produce carcasses which are soft, watery, and lack the fat necessary for the production of cured meats. The carcasses are

therefore sold fresh, the heavier ones enjoying a considerable demand in certain areas. The number of these on the market is of course very small. Many of them are sold ungraded.

Feeder and stocker pigs and hogs. The only difference between slaughter pigs and feeder pigs is that the former are purchased for slaughter and the latter for further feeding. Few pigs of either class are found at the larger markets. The principal markets for feeder pigs, in addition to local auction centers, are at South St. Paul, Kansas City, and Sioux City.

Agricultural Marketing Service Classification. The latest revised classification schedule for market hogs is the one tentatively recommended by the Agricultural Marketing Service of the U.S. Department of Agriculture, as shown in Table 169.[35] This system is the one now used in the Federal market-reporting service.

SELLING HOGS BY CARCASS WEIGHT AND GRADE

During the recent past a rather urgent demand has developed among pork producers and breeders for some system of pricing or evaluating market hogs that would more accurately reflect their true cut-out or carcass value. Trade in hogs has been and still is largely based on considerations of weight and condition alone, with little discrimination being given to differences in grade or quality. Market quotations for butcher hogs, for example, largely consist of a listing of weights with their respective prices. The spread in the day's prices for a given weight group is narrow and often is due as much or more to a change in the demand-supply relationship during the day as it is to any differences in the grade of hogs offered.

Market hogs vary widely in carcass value. Live-hog values vary because of differences (1) in weight, (2) yield or dressing percentage, and (3) in the shape, finish, and quality of the carcasses which they produce. Hogs purchased at the same price under the same demand-supply conditions often display surprising differences in cut-out value. Tests made at the Geo. A. Hormel & Co. plant at Austin, Minnesota, by Engelman and associates of the Minnesota Station[36] during the two-weeks' period from September 29 to October 11, 1947, showed an average difference of 38.5 cents per 100 pounds live weight between the price paid on foot and the actual cut-out value. Butcher-hog prices averaged $28.40 per hundredweight during the period.

[35] Don J. Slater, Cir. No. 569, U.S.D.A.
[36] Gerald Engelman, Austin A. Dowell, E. F. Ferrin, and P. A. Anderson, Tech. Bul. 187, 1950.

Table 169. Market Classes and Grades of Swine

Class	Slaughter Hogs Weight	Grade
	lb.	
Barrows and gilts	120–140 140–160 160–180 180–200 200–220 220–240 240–270 270–300 300–330 330–360 360–400 400–up	Choice (fat type) Choice (meat type) Good Medium Cull
Sows	270–300 300–330 330–360 360–400 400–450 450–500 500–600 600–up	Choice (fat type) Choice (meat type) Good
Stags	All weights	Ungraded
Boars	All weights	Ungraded
Unclassified	All weights	Ungraded
All classes	Under 30 30– 60	Ungraded
	60– 80 80–100	Good Medium Cull
Barrows and gilts	100–120	Choice Good Medium Cull
Feeder and Stocker Hogs and Pigs:		
	lb.	
Barrows and gilts — Hogs	120–140 140–160 160–180	Choice Good Medium Cull
Barrows and gilts — Pigs	80–down 80–100 100–120	Choice Good Medium Cull

In the test there were 40 lots of five hogs each, representing five weight classes with 20- or 30-pound intervals, from 180 to 300 pounds. In about one-half the lots the price paid on foot was greater than the carcass cut-out value justified; in about an equal number they were priced below their actual value. The largest difference for any lot was $1.33 per 100 pounds, and the smallest 1 cent.

For comparison, the carcasses were rail-graded, using the objective standards of backfat thickness and carcass weight shown in Table 170. From these tests the authors calculated that the relative pricing accuracy of the two methods, buying on foot and rail-grading based on their recommended carcass standards, was 45 percent and 83 percent, respectively.

Significant recent studies. The most important attempt yet made to establish objective standards (based on pounds, inches, etc.) for evaluating hog carcasses was begun by Engelman and associates of the Minnesota Station in 1946 [37] with the cooperation of Geo. A. Hormel & Co., packers of Austin, Minnesota. Detailed measurements were taken of 695 carcasses grouped in weight classes, with intervals of 10 pounds, from 115 to over 205 pounds. After cooling each carcass was subjected to a detailed cut-out test with values based on the average prices of the wholesale cuts and trimmings for the period from 1937 to 1941.

The high-value parts of a carcass are represented by the hams, loins, Boston butts, picnics, bellies—known as the five primary cuts—and the lean trimmings. In this study the total weight of these as a percentage of the total carcass weight was used as the "index of lean." Although the belly is a fat cut, it was included in the index of lean because of its high value.

Index of lean and backfat thickness indicators of value. Analysis of the test data showed a very high negative correlation between the average depth of backfat and the index of lean (–.8589); that is, as the backfat increases, the index of lean decreases to about the same degree. Length of carcass was found to be positively associated with the index of lean in carcasses of the same weight class, the reason being that such carcasses are less fat. Any influence which length may have on the index of lean, consequently, is exerted through its relationship to the amount of backfat. Length was found to have little influence independently on the index of lean.

[37] Gerald Engelman, Austin A. Dowell, E. F. Ferrin, and P. A. Anderson, Tech. Bul. 187, 1950.

Lean carcasses have a high percentage of lean cuts or index of lean, and fat carcasses a low percentage. But carcasses with the highest index of lean, or percentage of high-value cuts, were found in this study to be less valuable than carcasses with an intermediate index. This is because a certain amount of fat is necessary to impart to the lean cuts the quality required for the production of high-grade products. Any fat above this optimum point results in lowering the carcass

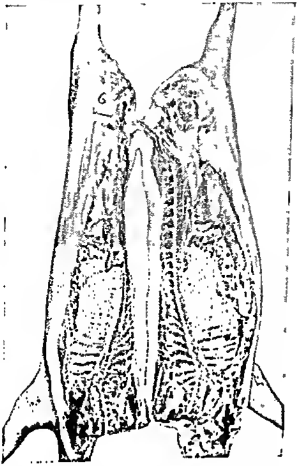


Fig. 67. Grand champion carcass at the 1950 National Barrow Show, shown by Bi-Lane Farms, Pennville, Ind., a purebred Hampshire; live weight, 218½ pounds; dressing yield, 71.9 percent; depth of back fat, 1.6 inches; and length (first rib to aich bone), 30.3 inches.

value, due chiefly to the low price of dry-salt fatbacks, clear plates, jowls, and lard. The value of the carcass increases as the index of lean increases only up to the point where, because of a lack of fat, some of the wholesale cuts are penalized for lack of finish or quality. Based on the 1937 to 1941 average wholesale prices for the different cuts, the optimum value for the index of lean was found to be located in

the neighborhood of 70. This point presumably will shift up or down as the relative prices of the high- and low-value cuts change in their relationship to one another.

Carcass grade standards. Tentative grade standards based on carcass weight and backfat thickness were thus developed for measuring desirability of carcasses, as shown in Table 170. Carcasses with a lean index around 70 percent had the highest cut-out value, based on average prices of the wholesale cuts from 1937 to 1941, and are given the Grade 10. Carcasses with a higher or lower percentage of lean or high-value cuts are placed in lower grades: the former, Grades 11 and 12, because some of the cuts, especially the bellies, lack sufficient fat to escape a discount in price; the latter, Grades 8 and 9, because of excess fat and the low value of fat trimmings and lard.

In February 1950 the Livestock Branch of the Production and Marketing Administration of the U.S. Department of Agriculture proposed the carcass grade standards shown in Table 171. These are basicly similar to the Minnesota standards just reviewed, but with a different tabular arrangement of the grades.

Table 171. Schedule of Proposed Carcass Measurements for Grades of Slaughter Barrows and Gilts (U.S.D.A.)

Weight (lb.)		*Average Backfat Thickness[a] of Carcass, by Grade*				
Live (Approx.)	*Carcass*	*Choice No. 1*	*Choice No. 2*	*Choice No. 3*	*Medium*	*Cull*
		inches	inches	inches	inches	inches
140	92					
		1.46–1.73	1.74–2.02	2.03 or more	1.03–1.45	1.02 or less
170	115					
		1.51–1.78	1.79–2.07	2.08 or more	1.08–1.50	1.07 or less
200	138					
		1.57–1.84	1.85–2.13	2.14 or more	1.13–1.56	1.12 or less
230	162					
		1.62–1.89	1.90–2.18	2.19 or more	1.18–1.61	1.17 or less
260	187					
		1.68–1.95	1.96–2.24	2.25 or more	1.24–1.67	1.23 or less
290	213					
		1.74–2.01	2.02–2.30	2.31 or more	1.30–1.73	1.29 or less
320	240					

[a] Average of three measurements made opposite first and last ribs and last lumbar vertebra.

A Choice No. 2 carcass ranks below a Choice No. 1 carcass, and a Choice No. 3 below a Choice No. 2, because of excess fat. Both No. 2 and No. 3 Choice are strictly choice carcasses, comparable to Grades

Table 170. Hog Carcass Grades Based on Backfat Thickness and Carcass Weight, Modified 0.3-inch Range of Backfat per Grade,[38] with Grade 10 Centered at Index of Lean of 70[39]

Carcass Weights, Pounds	Approximate Equivalent Live Weight, Pounds	Management Items	Carcass Grades 8	9	10	11	12
110-140	165-205	Backfat thickness, in.	2.3–2.0	2.0–1.7	1.7–1.4	1.4–1.1	1.1–0.8
Av., 125		Index of lean	62.6–65.6	65.6–68.5	68.5–71.4	71.4–74.4	74.4–77.3
140-180	205-260	Backfat thickness, in.	2.5–2.1	2.1–1.8	1.8–1.5	1.5–1.2	1.2–0.9
Av., 160		Index of lean	62.2–65.9	65.9–68.6	68.6–71.4	71.4–74.1	74.1–76.9
180-220	260-310	Backfat thickness, in.	2.6–2.2	2.2–1.9	1.9–1.6	1.6–1.3	1.3–0.9
Av., 200		Index of lean	62.7–66.1	66.1–68.7	68.7–71.3	71.3–73.9	73.9–77.3
220-270	310-375	Backfat thickness, in.	2.7–2.4	2.4–2.0	2.0–1.7	1.7–1.3	1.3–1.0
Av., 245		Index of lean	63.0–65.5	65.5–68.8	68.8–71.2	71.2–74.5	74.5–76.9
[illegible]	[illegible]	Backfat thickness, in.	2.9–2.5	2.5–2.1	2.1–1.8	1.8–1.4	1.4–1.0
Av., [illegible]		Index of lean	62.6–65.7	65.7–68.8	68.8–71.2	71.2–74.2	74.2–77.4

[38] [illegible] grades which have 0.4 inch range: 110-180 pounds—Grade 8, 180-220 pounds—Grades 8 and 12; 220-270 [illegible] Grade 8, 9, 11, and 12.
[39] [illegible] Hog Carcass Grade, Minn. Agr. Exp. Sta., Tech. Bul. 187, 1950.

8 and 9 in the Minnesota schedule, but because of extra fat and a lower proportion of high-priced cuts, they are of lower value than the Choice No. 1. Medium and Cull carcasses, like the Grades 11 and 12 in the Minnesota schedule, are graded low chiefly because the finish or amount of fat carried is below the minimum required for the production of quality cuts.

Conclusions and discussion. Assuming that satisfactory standards have been, or may be, worked out for grading carcasses on the rail, there remains to be considered the practicability of this plan of selling hogs when applied to marketing conditions as they are in this country.

The following advantages are claimed for the plan of selling by carcass weight and grade:

1. In this system slaughter hogs would sell more nearly at their true cut-out value. In the plan now in use hogs of the same weight class generally are sold within a price range too narrow to accommodate the differences in their actual carcass value. Tests have shown that live-hog grading, even when performed by the most discriminating packer buyer, is less accurate than rail grading. Also, it is claimed that carcass grading is more impartial than live-hog grading since it would be performed by specially trained Government experts.

2. When superior hogs command the premium which they deserve by their carcass value, and inferior hogs are discounted according to their deserts, the producer will have a greater incentive than he now has to improve the quality of the hogs he markets.

3. The plan would automatically do away with the wasteful practice of excessive filling of hogs at the market.

4. Producers would receive, along with the carcass grade report, definite information concerning softness and any bruising or condemnation losses. Although this loss probably would be distributed among all hogs marketed, the knowledge would emphasize the need of more careful methods of handling and disease control.

5. It is claimed that selling by carcass weight and grade would make possible the use of more accurate language in reporting market prices as well as encourage greater uniformity in the methods employed by the market reporting services.

6. Selling hogs by carcass grade has been proven efficient and practical in Denmark, Sweden, Great Britain, and Canada. In Canada, where the system is optional with the farmer, it has increased rapidly after its experimental introduction in 1934.[40]

[40] Geoffrey Shepherd, Ia. Agr. Exp. Sta., Bul. 353, 1937.

7. The cost of carcass grading has not proved excessive. Estimates in 1940, based on Canadian experience, placed the probable cost in this country at 2 to 3 cents a head, or about 1 cent per hundredweight.[41]

Difficulties in applying carcass grading. On the other side, a number of important reasons have been advanced to explain why selling slaughter hogs by carcass weight and grade generally would not be practicable in the United States:

1. Because of the wide variety in the demand for pork products, the result of relative purchasing power and differences in climate, custom, etc., it would be difficult if not impossible to maintain any given grade standard as a basis for evaluating hog carcasses throughout the country. New England, for example, prefers heavy hams and thick bacon, while the Baltimore market demands light cuts and lean bacon. There is no weight and grade which is preferred by all markets at the same time, and no weight and grade which is preferred at all times by the same market.[42]

The situation in the countries that have adopted carcass grading is quite different. There, the chief demand is for the type of hog that will produce a Wiltshire side that will meet the specifications laid down by the British bacon curers. These specifications are definite and do not change with the season or year.

2. The rail-grading system of evaluating hogs would be difficult in practice, also, because of the fluctuations which normally occur in the number, weight, and condition of the hogs marketed from season to season, and between different markets at the same time. Prices are influenced not only by the quality of the product, but also by the demand-supply relationship. This relationship changes with the season, and on a given day may be different at different markets. It might conceivably be responsible at times and places for No. 2 or even No.

mittees, and usually are set and published in advance by a week or month. Certain controls also have been used to secure more even seasonal supplies.[43]

3. What appears to be one of serious obstacles to the general application of the carcass-grade system of selling hogs in this country is the impossibility of making an immediate settlement on delivery. Even when the farmer sells direct to a local packer, full payment can be made only after his hogs have been killed and the carcasses graded. However, this would not involve a long delay, and any objection to it by the farmer can be largely overcome by the immediate payment on delivery of, say, 90 percent of the estimated amount.

But when the farmer sells to a dealer, country packer buyer, or consigns his hogs to a cooperative, which together handle more than one-third of all the commercial hogs marketed, the situation becomes very much more complicated. From these assembly points his hogs most likely will be mixed with others and shipped to one or more—sometimes distant—markets. Here, some of them may be purchased by an order buyer for reshipment to Eastern or Pacific Coast slaughterers. Two-thirds of the hogs marketed in Indiana in 1947, for example, were shipped to Eastern packers, situated chiefly in Baltimore, Boston, and Western Pennsylvania.[44] In any of these situations, final settlement would be long delayed.

There also would be the problem of maintaining the identity and ownership of the hogs all along the marketing route. This would not be so difficult with stencil branding. But if the farmer is to be paid on the basis of the carcass value of his hogs, it would necessitate an amount of paper work on the part of the intermediary handlers in keeping their records straight and reporting the grading results, as would seriously endanger, if not make impossible, the success of the plan.

Selling hogs by carcass weight and grade would appear to have its best chance of success when applied to hogs sold directly to a local packer whose products are designed to meet the requirements of some particular market. However desirable it may be, it appears extremely doubtful that the plan ever can be successfully applied generally in this country.

Producers believe they have a just complaint, however, in insisting

[43] Geoffrey Shepherd, Ia. Agr. Exp. Sta., Bul. 353, 1937.
[44] Ramon Wilson and James R. Wiley, Ind. Agr. Exp. Sta., *Economic and Marketing Information*, Aug., 1950.

that the packer buyer generally fails to give adequate attention in the prices he bids to differences in quality and prospective cut-out value between different lots, particularly for droves belonging to the same weight class; and that he seems more concerned with making the average cost of his daily purchases conform to the average value of the products than he is in applying the same discrimination to the purchase of individual lots.

Part of this failure, undoubtedly, is due to custom and the inability of the average buyer, because of lack of training, to judge accurately the yield and cut-out value; part of it is the result of the fact that commission agents and producers do not always sort their hogs for weight and grade before offering them for sale. That both the selling and buying agents on the market are increasingly aware of these facts and have made efforts to correct them is indicated by reports of farmers and other market observers that some improvement along these lines has been made in recent years, particularly on certain markets. At least it appears that the best hope for the future lies not in any radical change in our present marketing system, but rather in further improvements of the plan which we now have.

XVIII *Factors Affecting the Price of Hogs*

Attention will be given in this chapter to a brief consideration of the more important factors which affect the price of hogs. The attempt is made to explain why prices vary from year to year, season to season, and day to day. A general understanding of the facts and principles involved will be useful to the producer in determining the number of sows that should be bred in a given season, the method of feeding most profitable to employ in feeding out the pig crop, and in determining the time of marketing. He should be able to judge general market conditions with more understanding, to see farther ahead, and to adjust his hog production program more successfully to market needs.

The relation of supply and demand. The market price of hogs is the resultant of a large number of factors, some of which operate by affecting the supply and others by the influence which they exert on the

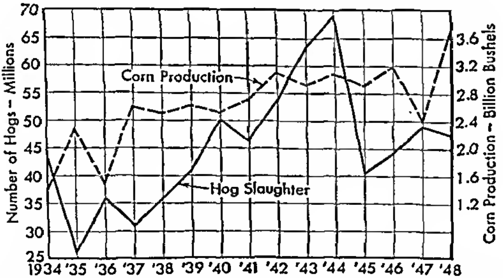


Fig. 68. Federally inspected hog slaughter and bushels of corn produced annually in the United States, 1934 to 1948, inclusive *(Feed Statistics, Statistical Bul. No. 85, U.S.D.A., 1949, and U.S.D.A.,* Livestock Market News, *C.S.-38,* 1949*).*

demand. The total pork supply for the year is chiefly determined by the number of sows bred and farrowed, the state of the weather during the farrowing season, the average weight of the hogs marketed, and disease losses. The strength of the demand is affected mainly by the level of consumers' income, the export demand, population growth, dietary habits of the consumer, and the prices of substitute foods.

The price received for hogs, barring short-time fluctuations, is determined by the relative strength of the supply and demand factors. When the immediate and prospective supply of hogs increases, and the demand does not change, prices decline. And when the demand increases and the supply remains constant, prices advance. When the change in supply just balances the change in demand, the prices remain unchanged. Falling prices may be due either to increased supplies or decreased demand; rising prices may result either from a deficiency in the supply or increased strength in the demand. High prices stimulate production; low prices stimulate consumption.

FACTORS WHICH AFFECT THE SUPPLY OF PORK

farm slaughter and slaughter at plants without Federal inspection.[1]

The hog-corn ratio affects future pork supplies. In normal times the most important influence affecting the farmer's decision as to the number of sows to breed seems to be the relation between feed prices, especially of corn, and the price of hogs during the months immediately preceding and during the breeding season. This relationship is known as the "hog-corn" or "corn-hog" ratio, and means the number of bushels of corn required to equal in value 100 pounds of market hogs. A hog-corn ratio of 11, for example, means that the prices are such that 11 bushels of corn are equal in market value to 100 pounds of market hogs. It may be based either on Chicago or farm prices.

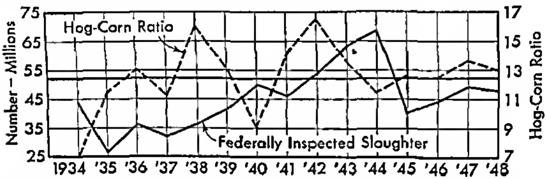


Fig. 69. Federally inspected slaughter of hogs and the hog-corn ratio (farm prices) by years, 1934–1948 (*U.S.D.A.,* Livestock Market News, *C.S.*-38, 1949).

In Fig. 69 the broken line represents the average number of bushels of corn required to equal in value 100 pounds of market hogs, farm prices considered, for each year from 1934 to 1948, inclusive. The heavy straight horizontal line in this figure represents the ratio of 12.6, the average for the period. The so-called historical ratio, or long-time average ratio during normal times, is 11.4. A high hog-corn ratio, one above the average, means relatively cheap corn and high-priced hogs; a low ratio means relatively high-priced corn and a low market price for hogs. The effect of a low or unprofitable ratio is to cause a reduction in the number of sows bred during the next subsequent breeding season; a high ratio, on the other hand, tends to result in the breeding of an increased number. The effect of this natural response on the part of the farmer is to cause an increase or decrease in the number of hogs marketed 12 to 18 months later, depending on whether the ratio was low or high.

The degree to which production is affected by the hog-corn ratio is

[1] *Agr. Statistics,* U.S.D.A., 1948.

shown by the relationship between the price ratio during the breeding period, September to December, and the number of sows farrowing the following spring, from 1924 to 1950, as reported by the Bureau of Agricultural Economics.[2] When the ratio during the fall breeding period was 14.7 to 17.2, there was an average increase of 16.5 percent (5.1 to 27.9) in the number of sows farrowing the following spring compared with the preceding spring; when the ratio was 11.2 to 14.5, there was a decrease of 4.4 percent (—24.1 to +8.6); when the ratio was 6.8 to 11.2, the decrease in the number of sows farrowing amounted to 9.4 percent (—25.2 to +8.3).

In normal times the hog-corn ratio cycles tend to move in opposite directions to those of the production or slaughter cycles, which generally are of 3 to 5 years duration. Price-control measures adopted by the Government during the war period, represented by ceiling prices on market hogs during 1944, 1945, and 1946, and support prices from 1941 to 1950, together with the patriotic response of farmers to the need for increased food production, were influences which modified the usual or normal relationship. Other factors which tend to obscure the usual relationship are the state of the weather during the farrowing season, extent of disease losses, severe droughts, such as occurred in 1934 and 1936, and low wheat compared with corn prices.

Although other factors may influence hog production above or below the normal or average, the dominant factor responsible for the periodic shifts which occur every 2 to 5 years is the hog-corn price relationship which existed during and immediately preceding the breeding season, and the size of the corn crop. Since 12 to 18 months must intervene between the time the sows are bred and the pigs marketed, and because the farmer is guided in his breeding plans more by present than anticipated prices 12 to 18 months later, these changes in production tend to be extreme and often violent. The ideal situation with respect to the supply and price of pork would be an annual production just sufficient in volume that the consumer would take it at a price just sufficiently high to ensure a profit to the producer and continued production.

DEMAND FACTORS AFFECT PRICES

Consumer's income of basic importance. Of the factors which determine hog prices, as well as that of other [illegible]

[2] U.S.D.A., *Livestock and Meat Situation*, LMS-[illegible]

income is probably the most fundamental and important. Full employment and high wages mean the ability either to take an abnormally large supply of pork at average prices, or a normal supply at prices considerably above the average. When times are hard, on the other hand, below-normal supplies may fail to bring even average prices. Studies have established the principle that the general level of hog prices is determined at the point where, under the demand conditions, the supply will just move into consumption.[3] The record low prices for hogs in 1932, 1933, and 1934 were the result of the severely limited buying power on the part of the industrial population, due to the acute business depression at home and abroad, and not to an abnormally large pork supply. The supply could be moved into consumption only at this low price level.

An increase in consumer demand for pork products is registered first at the retail shop or store in the willingness of the public to buy increasing quantities at a given price or to pay higher prices for a limited supply. This increased demand is reflected on the wholesale market in orders of larger volume or at higher prices, from which point it is carried, in turn, by the packer to the live-hog market. The demand will finally be registered in higher live-hog prices as a result of the competition among packers for the available supply of hogs.

The farmer, in the last analysis, really has little to say concerning the price his hogs bring on the market, especially in affecting the general hog-price level. After his pig crop has been produced, the best he can do is to choose the time and place of marketing wisely, although he can influence the supply by varying the finished market weight. The price level cannot be pushed above the consumer's capacity or willingness to pay; but, when allowed to operate without Government intervention, the competition among the retailers will guarantee that the prices paid by the consumer will be close to the maximum limit, while competition among the retailers, wholesalers, and packers, respectively, will guarantee that the prices paid by the consumer will, after operating margins have been deducted, be expressed in the general level of live-hog prices.

Consumer's income modified by purchasing power of money. It is important to observe here that the real purchasing power of the consumer's income is affected markedly by changes in the value of the dollar. Full employment and high wages were not responsible alone for

[3] G. C. Haas and Mordecai Ezekiel, U.S.D.A., Dept. Bul. 1440, 1926; U.S.D.A., Misc. Pub. 222, 1935.

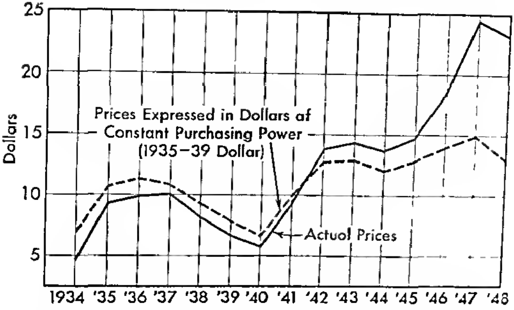


Fig. 70. Average annual price of hogs per hundredweight at Chicago from 1934 to 1948, inclusive *(U.S.D.A.,* Livestock Market News, *C.S.-38.* 1949*)*.

the high hog prices registered during World War II and subsequently. a considerable part of it was the result of cheap money. Had the purchasing power of the dollar been constant, the year-to-year average Chicago prices from 1935 to 1949 would have been as shown by the dotted curve in Fig. 70, based on the average purchasing power of the dollar from 1935 to 1939, inclusive.

Packers' and distributors' margins. It will be interesting here to observe the portion of the consumer's dollar paid for pork which is taken by the various agencies concerned with the processing, handling, and retailing the products. Bjorka of the Bureau of Agricultural Economics [4] made such a study, the results of which are shown in Table 172.

After the costs and profits for the services performed by the retailer,

Table 172. Value and Margins per 100 Pounds of Edible Pork, 1935

Item	*Amount per 100 Pounds*	*Percentage of Total*
Consumers' average cost	$[illegible]	[illegible]
Average retail margin	$ 5.70	[illegible]
Average wholesale margin	$ 3.2[illegible]	[illegible]
Average margin for processing	$ 4.71	[illegible]
Average proceeds to farmers	$10.33	[illegible]
Transportation costs, etc. on live animals	$ [illegible]	[illegible]

[4] Knute Bjorka, U.S.D.A., [illegible]

wholesaler, and packer have been deducted, there is left for the farmer only 40 cents of the consumer's dollar, to pay for his service as producer.

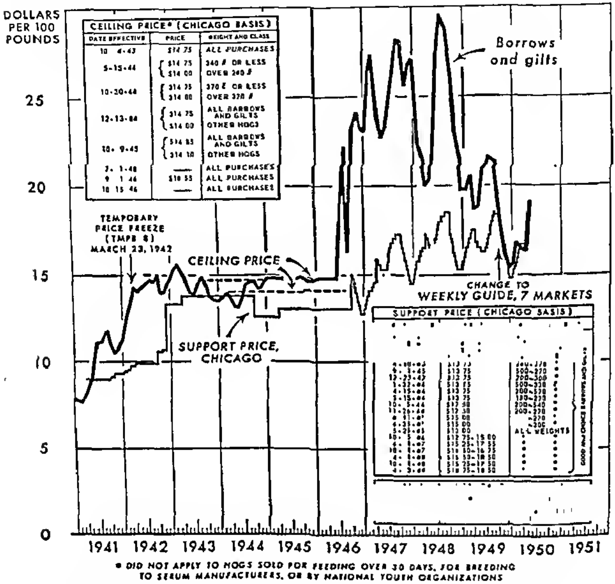


Fig. 71. Prices of barrows and gilts purchased at Chicago, 1941–1950; the support and ceiling prices in effect *(courtesy, U.S.D.A., Bu. Agr. Ec.).*

Bjorka's studies also showed that salaries and wages represented the largest item in the cost of the different marketing functions for all classes of meat animals. For marketing livestock (exclusive of transportation) 49 percent of the operating expenses was paid for labor; for meat packing, salaries and wages amounted to 51 percent of the total operating expenses; for wholesaling it was 52 percent (exclusive of transportation); and for retailing, salaries and wages represented 58 percent of the cost. The total cost to the packer for processing

pork is greater than for other meats, but the retailing cost is correspondingly less.

If the price of live hogs rises as labor and other costs increase, as they do in the long run when unfettered by controls, the percentage of the consumer's dollar received by the farmer would be expected to remain fairly constant through the years. This assumes, of course, that processing costs are not increased by further improvements in merchandising techniques.

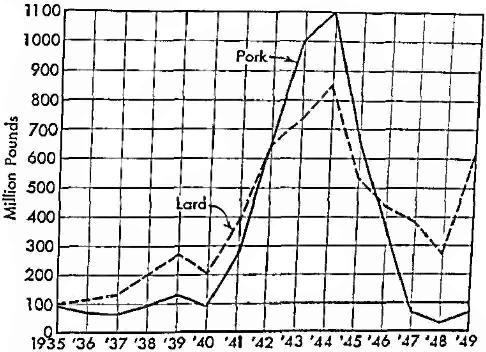


Fig. 72. Pork and lard exports by the United States, 1935 to 1949, inclusive (*U.S.D.A.*, Livestock Market News, *C.S.*-38, 1949).

Export demand may affect prices. Except in war times, the volume of pork exports by the United States is so small, compared with the total production, that its influence on hog prices is relatively unimportant. In Fig. 72 there is pictured the pounds of pork (fresh, cured, and canned) and of lard (including rendered pork fat) exported annually from 1935 to 1949, inclusive.

During this 15-year period the exports of pork represented 3.3 percent of the total slaughter, while lard exports amounted to 18 percent of the total production. For the 6 prewar years, 1935 to 1940, however, pork exports amounted only to 1.1 percent of the total slaughter, and lard exports only to 9.8 percent of the production.

We import some pork products, but the amount, which from 1940 to 1949 represented less than one-tenth of 1 percent of the tonnage exported, is little more than a trickle.

Population increase affects demand. The expansion which has occurred in the number of hogs produced in the United States has paralleled in general the growth in population. From 1800 to 1900 the population increased by more than 1300 percent (5,308,483 to 75,994,575). From 1900 to 1950 the number of people was almost doubled by an increase of 97 percent. During the past two decades, 1930 to 1950, the increase has been 22 percent (122,775,046 to 150,000,000, predicted), or at the rate of 1.1 percent annually.[5]

The danger of surplus pork production and ruinous prices in the future does not appear to be great, therefore, so long as the buying power of the people is not reduced through industrial unemployment. Also, the urban or city population has increased much more rapidly than has the rural population. In 1800 the country population constituted 93.9 percent of the total; in 1850 it was 84.7 percent; in 1900, 60.3 percent; while in 1940 it was only 43.5 percent of the total.

Dietary habits of the consumer. The general substitution of machine for manual labor both on the farm and in the industries, as well as the decline in rural compared with the urban population, are undoubtedly responsible for some weakening in the demand for pork and other meats. Along with this change there have come year-round supplies of fruits and fresh vegetables, and the teachings of the dietitian in favor of greater variety and vitamins, with the result that the housewife now is inclined to place less dependence on meat than she did formerly.

Dietary habits are markedly affected by economic conditions. When these are bad, as a result of war or maladjustments in the pork supply, there tends to be established the habit of low consumption, thus weakening the demand. The producer, however, may take some encouragement from the nation-wide educational campaign which is being aggressively waged by the National Live Stock and Meat Board[6] in bringing effectively to the attention of the consuming public the superior nutritive qualities of meat and its right to continue to occupy the central place in the diet of the American people.

Price of substitute foods affects demand for pork products. Although pork is the poor man's meat, the demand for it is affected by the availability and prices of substitute foods. Canned fish and other marine products represent one of these. The production of canned fish, oysters, clams, shrimps, etc., in the United States and Alaska increased

[5] U.S. Census Bureau Rpts.
[6] R. C. Pollock, Gen. Mgr.

246 percent from 1939 to 1948.[7] This was augmented by the importation in 1948 of 57 million pounds. Money spent for these food products increased by more than four times from 1939 to 1948. Also, when meat prices are high and consumers' income low, less pork and more cereals are eaten. Poultry consumption has increased enormously in recent years.

The extensive substitution of vegetable shortenings for lard that has occurred during the past 20 years has seriously depressed the demand for lard and consequently affected the price of hogs. Lard and rendered pork fat constitute from 12 to 15 percent of the hog's live weight. From 1939 to 1948, inclusive, the Chicago wholesale price of refined lard averaged but 1.46 cents per pound above Chicago live-hog prices.[8] Thirty years ago lard represented 20 percent of the value of the dressed hog; today it probably represents less than 10 percent.

SEASONAL VARIATION IN PRICE

The supply of market hogs varies with the season. The seasonal variations which are characteristic of market receipts are the result of the seasonal nature of the farm hog-production program (see Table II, Chap. II). The extent of these variations is shown by the solid line in Fig. 73, which is based on the average percentage of the hogs slaughtered by months for the 10-year period 1930 to 1939, inclusive.

This prewar period was selected to show the relation between seasonal supplies and seasonal prices, rather than a more recent one, because it was believed that the normal relationship was less disturbed by the production control measures taken under the Agricultural Adjustment Acts of 1933 and 1938 than by the Government's price-control and price-support programs during and subsequent to World War II.

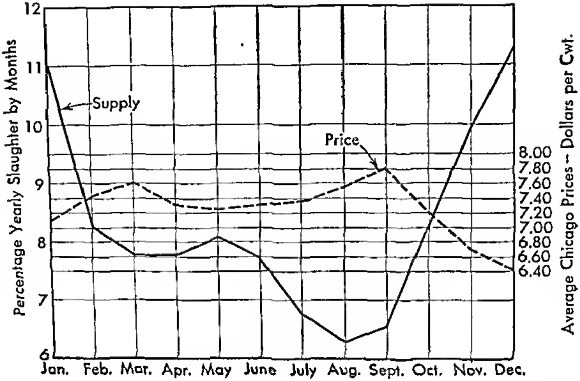


Fig. 73. Percentage distribution of federally inspected slaughter of hogs by months, 1930 to 1939, inclusive, and monthly average Chicago prices 1930 to 1939, inclusive *(U.S.D.A.,* Livestock Market News, *Statistical Bul. No.* 91, 1950*)*. Purchases on Government account for Emergency Hog Control Program from August 22 to October 7, 1933 are excluded.

September; those farrowed late and fed full rations only after the new corn crop becomes available may be marketed as late as February. The bulk of the spring crop, however, arrives in November, December, and January. Most of the fall pigs are marketed the following summer, with the peak of the receipts usually in April or May. The decline in receipts during July, August, and September means that most of the fall pigs have been sold and that general marketing of the spring crop has not started. A considerable proportion of the receipts during late summer is represented by packing sows.

There are exceptions, of course, to these general rules and averages. In the western Corn Belt, where the single-litter plan of production is more often followed, the pigs are farrowed late, and later than average marketing results. In the eastern Corn Belt, on the other hand, where the two-litter system of production is practically universal, early farrowing and more intensive feeding is the rule, with the result that the pigs reach market earlier than is characteristic for the commercial supply as a whole. Market receipts in the South naturally vary less with the season than those in the North.

There are some departures from this normal distribution also due to the state of the market and the feed supply. When feed is scarce and hogs low in price, it may result either in a postponement of heavy feeding with later-than-usual marketing, or to earlier-than-usual marketing at immature weights if the outlook for the corn crop is unfavorable. Also, during years when hog numbers are being increased, as occurs following periods of heavy corn crops, marketings during the autumn and winter will be above average; while during years of declining production the proportion of the year's receipts during the early part of the year will tend to be above normal.

The slaughter data given in Fig. 73 are based on number of hogs and not on total weight. The average weight of barrows and gilts (butcher hogs) from February to July at the seven principal markets from 1939 to 1948, inclusive, averaged about 10 pounds heavier than those marketed from August to the following January. Heavy receipts of packing sows during July, August, and September raise the average weight during the late summer.

Seasonal price changes and their causes. The average monthly price (actual) of hogs on the Chicago market from 1930 to 1939, inclusive, is shown by the broken line in Fig. 73. Like the supply, the price varies from month to month throughout the year, but in the opposite direction. Normally and on the average, prices are highest in August and September and lowest in December and January, while receipts are lightest in August and September and heaviest in December and January. This relationship conforms to normal expectancy.

Prices for the individual years, however, do not follow exactly this normal, although they tend to. Only twice during this 10-year period was the highest average price recorded in September. In two years they were highest in February, and in each of the remaining years, excepting June, once during the period. When prices are on the upgrade, autumn and early-winter prices will be relatively high for the year's average, while during years of declining prices they will be below normal. The premium for early-marketed spring pigs is greatest when prices are tending downward, and least when on the ascending side of the price cycle.

A study of the month-to-month fluctuations in receipts and prices reveals the rather significant fact that receipts vary much more widely than do prices. In fact, during this 10-year period the coefficient of variation for receipts was four times that for prices. This fact was taken into consideration when plotting the two curves.

Seasonal price changes differ for different weights. Prices both for light and heavy hogs are highest on the average in September and lowest in December and January; but the spread in prices between light and heavy hogs varies with the season. Hogs weighing 190 to 230 pounds are in strongest general demand because they furnish the weight and quality of cuts required in largest volume by the consumer. The demand for the products of heavy butcher hogs, weighing from 250 to 300 pounds, on the other hand, is much more limited. Because of seasonal fluctuations in the supply, however, there are times during the year when heavy hogs will sell for more than they would have brought on the market 1 or 2 months earlier as light hogs. This brings up the question of the most profitable weight to market the pig crop.

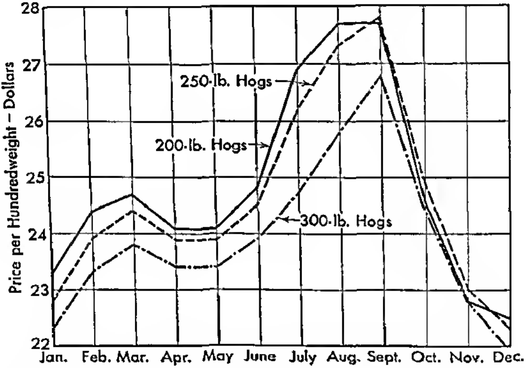


Fig. 74. Prices of good to choice butcher hogs at Chicago by months and weight classes, 1934 to 1941, inclusive, adjusted to prices in November, 1948.

At what weight should hogs be marketed? The two principal factors involved in determining the best market weight are the cost of producing the different weights and the prices the respective weights sell for during the different seasons of the year.

In Fig. 74 is shown the seasonal variation in the average monthly prices of good to choice barrows and gilts of different weights on the Chicago market from 1934 to 1941, inclusive, with the prices adjusted to those of November, 1948.[9]

[9] L. Jay Atkinson and John W. Klein, *Feed Consumption and Marketing Weight of Hogs*, U.S.D.A., Bu. Agr. Ec., Tech. Bul. 894, 1945.

A study of these weight-price curves shows that 250-pound hogs in February sold higher than 200-pound hogs did in January, and practically as high in March as 200-pound hogs did in February. Also, in June, July, and August, 250-pound hogs were priced higher than 200-pound hogs the respective preceding months; and 300-pound butcher hogs in July sold higher than 250-pound hogs did in June.

Considering the very slight increase in the total cost of producing heavy compared with light hogs (see Chapter XVI), the following conclusions of Hadley and Bauman of Purdue University,[10] made after a careful study of all the factors involved, seem to be warranted:

1. With a very favorable feeding ratio, it pays to make 250- to 300-pound hogs except in the fall of the year. This advantage is expected to be greatest in feeding hogs weighing 200 pounds in May, June, or July to heavier weights for sale six weeks to two months later.
2. It seldom pays to carry hogs past 300 pounds.
3. With *normal feeding ratios,* it pays to market hogs at around 200 to 225 pounds except in December and January, and again in the late spring and early summer when they usually can be profitably fed 50 pounds heavier.
4. It seldom pays to carry 200-pound hogs beyond September, due to the sharp seasonal price decline which usually occurs in the late fall and early winter.

Cold storage holdings. The price of hogs does not fluctuate during the year as much as does the supply because of the important function performed by the cold-storage facilities of the packer. By the accumulation of large storage supplies during the heavy run of market hogs in the winter and the withdrawal of these supplies during the summer when current receipts of live hogs are low, the packer is enabled to equalize the seasonal supply of pork products to the consumer. The per capita consumption of pork products varies remarkably little during the year.

During the period 1940 to 1949 cold-storage holdings of pork products, which included dry-salt, pickled, frozen, cured and in process of cure, amounted to a minimum of a little more than 242 million pounds on November 1, on the average, and to an average maximum of more than 598 million pounds on March 1.[11] During the four-months period from March to July the volume going into storage about equals the amount withdrawn from storage. From November to February the stocks going into storage greatly exceeds the amount withdrawn; during the late summer and early fall the withdrawals

[10] N. S. Hadley and R. H. Bauman, *Successful Farming,* Feb., [illegible]
[11] U.S.D.A., *Livestock Market News,* Statistical Bul. No. 91, [illegible]

greatly exceed the volume going into storage. Clemen reports that from 1917 to 1920 inclusive 20 to 30 percent of the pork going into consumption during July, August, September, and October was represented by storage stocks.[12]

This carry-over of surplus pork stocks from the season of heavy to the season of light market receipts is so efficiently performed that the effect of the seasonal variations in market receipts on prices is practically nullified. The differences in the price received for live hogs during the different seasons of the year are little more than is sufficient to pay the costs of storage. It appears, therefore, that the normal seasonal variations in the price of hogs are the result more of the larger margin required by the packer on hogs purchased in the winter, a large proportion of which goes into storage, than it is to the variation in market receipts.

Locker and home-freezer units provide important storage facilities. The facilities now supplied by frozen-food-locker plants, deep-freeze units, as well as the 30 million refrigerators in use in American homes, may affect the week-to-week demand for meat. The Bureau of Agricultural Economics [13] reports that the estimates on the number of deep-freeze units in use vary from 2.25 to 3 million, and that there are 5 million lockers available in freezer locker plants throughout the country. The combined storage space of these units, about one-half of which is used for meat, is estimated to be considerably larger than the total freezer space in commercial storage plants. About two-thirds of the freezer lockers are rented by farmers.

The extent to which these storage supplies are laid in during the months of surplus production and withdrawn during periods of deficit supplies, they will supplement the storage facilities of the packer and tend further to help reduce the weekly and monthly changes in the price of pork and hogs.

DAILY FLUCTUATIONS IN SUPPLY AND PRICE

Considerable variation in the daily supply of hogs characterizes the receipts at the large public markets. Studies by the Bureau of Agricultural Economics [14] of the daily runs at the Chicago market in 1931, 1932, and 1933 showed the following with respect to the average distribution of those consigned for sale (not including directs): Monday

[12] Rudolf A. Clemen, *The American Livestock and Meat Industry*, The Ronald Press Co., N.Y., 1923.
[13] U.S.D.A., *Livestock and Meat Situation*, LMS-43, Sept., 1950.
[14] U.S.D.A., Misc. Pub. No. 222, 1935.

28 percent; Tuesday 21 percent; Wednesday 18 percent; Thursday 19 percent; Friday 13 percent, and Saturday 1 percent. Of the hogs representing direct shipments to Chicago packers, 30 percent of the week's total arrived on Monday aud 15 percent on Saturday. The remainder was fairly equally distributed among the other days of the week.

Distribution of the receipts at the interior packing plants and concentration yards in Iowa and southern Minnesota during the same period was quite different from that of the central markets. They were characterized by the large number of arrivals on Saturday, which represented on the average more than 30 percent of the week's total. On the other days of the week arrivals were fairly evenly distributed, but with a tendency for the number to increase slightly from Monday to Friday. Most of these hogs are delivered by truck and represent "direct" purchases by packers, and the distribution seems to be a natural one. Saturday arrivals at the interior markets represent the supply with which the packer commences killing operations the following Monday.

The price of hogs fluctuates from day to day throughout the week, as does the supply, but quite independently of the supply apparently. The extensive studies made by the Bureau of Agricultural Economics, referred to earlier, showed that for packer purchases on the Chicago market, the Monday and Wednesday prices were as high, or higher, than the average of the week. This is interesting since the naturally heavy receipts of consigned hogs on Monday is augmented by the arrival of those purchased direct the previous Saturday. Although the supply constitutes less than 2 percent of the week's total, Saturday prices at the Chicago market are as low, or lower, than the average for the week.

supply which will be available on a given day, or to their inability to judge accurately the immediate demands of their trade. At the central markets, receipts above the normal for a given day tend to depress the price for that day, while supplies below the usual or expected number tend to raise the price. In other words, fluctuations in the daily supply affect prices only when they are above or below the normal for that day; the usual or normal changes in the day-to-day supplies during the week apparently have no effect.

SUMMARY

1. Hog prices vary from year to year because of changes in the relationship between the supply of hogs and the demand for pork products. The most important influences determining the number of commercial hogs produced in a given marketing year is the hog-corn ratio during and immediately preceding the breeding season and the available and prospective supply of corn. It is affected also by the weather during the farrowing season, disease losses, the prices of other hog feeds, and general business conditions. The important factors influencing the demand for live hogs are consumer's income, the volume of exports, storage supplies, population, dietary habits, and the price of alternative foods. The most important of these factors which affect year-to-year changes in the hog-price cycle seems to be the supply of hogs. The price actually paid may appear high or low also according to the purchasing power of the dollar.

2. The normal seasonal changes which occur in the price of hogs are the result chiefly of the seasonal character of hog marketings and the larger margins required by the packer to pay storage charges on the surplus supplies produced by the heavy runs during the winter. Consumer requirements are practically constant throughout the year. The more important of these two factors is the extra costs of storage attached to the handling of these surplus supplies.

3. Daily fluctuations in the price of hogs do not appear to be related to the variations which normally occur in the number of hogs arriving on the different days of the week at the central markets. Prices are as high on days which normally have heavy supplies as they are on days when normally but few hogs are marketed. When arrivals on a given day are above or below the expected or normal, however, the price will be affected. At the interior markets, supplies are usually heaviest on the days highest prices are paid.

The intelligent hogman may take advantage of these facts either by holding fairly closely to a plan of production which changes little

from year to year, or, if inclined to change, by varying his production to conform more to probable future rather than to present prices. The first plan is favored by the fact that changes in production from year to year are always accompanied by some increase in the costs of production; also the good hogman generally makes a profit, all factors considered, even in years when the hog-corn ratio is unfavorable. If he is inclined to vary his production, he should be influenced less by the present relation of corn and hog prices in determining the number of sows to breed, and more by what the ratio and demand are likely to be 12 to 18 months later when the pigs go to market. He will study carefully the federal reports on "Breeding Intentions" and "Pig Farrowings," published about December 30 and June 30 each year, as an aid in helping to forecast the subsequent year's supply.[15]

As a rule, farmers persist in reducing production so long as the hog-corn ratio is unfavorable, and they continue increasing production so long as it is favorable. Of course, when the carry-over of corn is no greater than it is, a short corn crop necessitates liquidation. The result is that the average man has most hogs to sell when the price is low, and fewest when they are high. It is also largely responsible for the extreme variations in the supply which occur from year to year and the economic loss to the industry which results.

The regularity with which hog prices change with the seasons promises higher prices to the farmer who markets his pig crop ahead of the general run. This can often be accomplished without increasing greatly the costs of production or of necessitating any radical change in the farm organization. A better class of breeding stock, more attention to sanitation, and better feeding practices than are common on the average farm are also means to this end.

The fluctuations which occur in the price of hogs from day to day emphasize the importance of orderly marketing of the available supply. By taking full advantage of the radio and other ready means of acquiring market news information, and particularly by keeping in touch with competing local markets, the individual farmer, or his cooperative, will be able to choose the time and place of marketing with more likelihood of avoiding market gluts with their price penalty.

[15] A national pig survey is conducted twice annually by the U.S. Bureau of Agricultural Economics with the cooperation of the U.S. Post Office Department on June 1 and December 1, the results being released at the end of the month. The reports include (a) the size of the pig crop farrowed during the previous 6 months as compared with the previous year, and (b) breeding intentions, for spring farrowing in the December report and for fall farrowing in the June survey.

XIX *Judging*

Success in the production of market pork or in the breeding of purebreds is determined pretty much by the judgment used in the selection of breeding stock and in evaluating the quality of the finished product. The primary essential for success is that the hogman must be a good judge. The ability to "size up" the individual accurately and quickly is a talent possessed by all successful breeders.

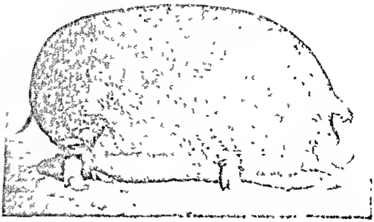
The basis for sound judgment. There are three important essentials involved in judging: first is the importance of having clearly in mind the ideal type; second is the necessity of observing critically the merits and faults of the individual; and third is the exercise of good judgment in weighing the good points against the faults in reaching a final decision. Of these three, the first is the one which most often is responsible for the failure of good judges always to agree.

Sound ideals call for utility standards. By sound ideals is meant that they are based on considerations of utility rather than on so-called fancy points. The ideal market barrow is one which will yield well and possesses the form, finish, and quality that will produce a carcass of the highest cut-out value. With the breeding classes, the ideal is a type which is most consistent with a high level of breeding performance. For efficient and profitable production the brood sow must be capable of (1) producing and raising large litters; (2) produce pigs with the capacity for rapid and economical gains; and (3) pigs which have the type and finish that will yield Choice No. 1 carcasses at the popular market weights of 180 to 240 pounds.

It is now generally agreed among practically all breeders that the type of hog which performs most acceptably in all three of these phases of production under present conditions is the so-called medium or intermediate type. But it was not always so.

TYPES OF HOGS

The old plan of classifying all hogs as belonging either to the lard or bacon type still persists, although it is generally recognized that the



A—The type of Poland China aged sow that was made Champion in 1911 *(photo by Allen).*

B—Champion junior yearling Poland China boar, 1930 *(photo by Smith)*

Since about 1925 the trend in the breeder's type has been away from this extreme and toward an ideal which seeks to retain all that was good in the so-called "big type" and to reclaim some of the qualities characteristic of the old lard type. This is a hog which combines size with smoothness and quality; one which possesses feeding capacity along with sufficient disposition to fatten during the growth period. The ideal includes also the possession of those traits which are associated with regular breeding performance. It is a type which satisfies the need of the farmer for a growthy, fast-gaining hog that fattens readily, and which meets the demands of the packer for a hog that yields well and furnishes cuts of a size and quality that meet the requirements of the consumer without necessarily adding to the surplus supply of lard. By about 1940 the type pendulum had swung back to a point intermediate between these two extremes.

Type-stabilizing influences. Considerable progress has been made in perfecting this intermediate type of hog since 1935. Several agencies or influences must be given large credit for the improvements which have been made during these recent years.

1. The *Ton-Litter Project* (a ton of pork from one litter in 170 or 180 days), which has been widely adopted by the college extension services throughout the country since its inception in 1922, has been a most potent factor in molding our conception type. It has done this by demonstrating the fundamental importance of large litters and superior feeding capacity in the production of our pork supply, and the type of hog which performs most consistently in these practical essentials.

2. The *Breed-Type Conferences,* held annually by a number of the National Breed Registry Associations ever since 1937, have contributed much to the evolution of more sensible type standards. They have emphasized in their judging demonstrations the importance of giving closer attention in herd selections and show-ring judging to those characteristics which are associated with reproductive ability and feed lot performance. And when supplemented with the judging of market barrows on foot followed by studies of their carcasses in the cooler, these type conferences have been the means of bringing about a better understanding among breeders of packer and consumer requirements.

3. Another significant development is represented by the adoption and promotion by most of the breed registry associations of the *All-Breed Production Registry Program,* sponsored by the National Association of Swine Records. This provides the means of giving special

two divisions are not so distinct as formerly. The classification has lost much of its former significance because the difference between any of the so-called lard breeds and the bacon breeds is much less marked today that it was prior to 1910. This is the result chiefly of changes which have occurred in the so-called lard breeds rather than in those of the bacon type. These have been brought about through changes in the type of hog demanded by the market and the pursuit of type fads by the breeders.

Changes in the breeder's type. Radical changes have taken place in the ideals of the breeder during the past 40 years. Antedating the beginning of this period, the extreme lard type dominated the show ring, especially from 1890 to about 1910. This was a hog which possessed to an extreme degree refinement and the disposition to fatten at an early age. He was thick, compactly built, stood on very short legs, and was small to medium in size. Because of this fad for the ultrarefined fat type, the utility qualities were pretty much lost sight of. The result was a hog which failed more and more to meet the practical requirements of the farmer. These demanded greater ability on the part of the sows to farrow and raise profitable-sized litters, and pigs which were capable of making more satisfactory gains up to a market weight of 250 pounds or more. A natural reaction among farmers against this type set in soon after 1900 and by 1915 began to be reflected in the decisions of the showring. This ended the reign of the refined ultrafat type (see Fig. 75).

Following 1910 and up to about 1925 the change which occurred in the type of most so-called lard breeds was in the opposite direction to that which obtained during the period just described. The thing sought by the breeder now was more size, growthiness, and prolificacy, instead of refinement and quality. The demand for size as an evidence in itself of feeding capacity soon became distorted into a demand for the ultrarangy type, characterized by long legs, high backs, and lots of bone. Thus the "big-type" craze was born. The demand for this type soon so dominated the breeder's selections that the importance of middle, quality, sufficient disposition to fatten, and ability to raise pigs was made secondary or lost sight of entirely. These extreme specimens of the big-type fad did not meet either the requirements of the farmer or the packer. From the market standpoint they had too much bone and skin, were too long in the shank, and were likely to be unfinished in condition. As a farmer's hog they were criticized because they did not fatten readily, killed too many of their pigs, and were deficient in general stamina. And so the tide changed again.

Since about 1925 the trend in the breeder's type has been away from this extreme and toward an ideal which seeks to retain all that was good in the so-called "big type" and to reclaim some of the qualities characteristic of the old lard type. This is a hog which combines size with smoothness and quality; one which possesses feeding capacity along with sufficient disposition to fatten during the growth period. The ideal includes also the possession of those traits which are associated with regular breeding performance. It is a type which satisfies the need of the farmer for a growthy, fast-gaining hog that fattens readily, and which meets the demands of the packer for a hog that yields well and furnishes cuts of a size and quality that meet the requirements of the consumer without necessarily adding to the surplus supply of lard. By about 1940 the type pendulum had swung back to a point intermediate between these two extremes.

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recognition to sows and boars which produce litters above a certain minimum in number of pigs raised and weight of litter at weaning time, the litters of which do not possess certain individual disqualifying features, such as one or more pigs with a swirl, hernia, "rigling," or certain disqualifying breed-type features. Here again emphasis is placed on production and the type with which it is most generally associated.[1]

4. The *Market Barrow Show,* which now has been given a classification at practically all state fairs, has not only been a source of keen interest, but it has functioned as a constant reminder to the breeder that the type of hog he breeds should be one which is not inconsistent with commercial market requirements. These, with the great national shows, such as the Chicago International, Kansas City Royal, and the National Barrow Show at Austin, Minnesota, have had a significant part in shaping our present improved type of hog and in securing among the breeds a uniformity in type which had not existed before.

These agencies have stabilized and unified our ideals concerning the type of hog best qualified to meet the requirements of the American pork producer; and their continuing influence gives assurance that the industry never again will be plagued with those radical type changes which we had during the earlier years.

JUDGING THE MARKET BARROW

Conflicting ideas concerning the standard or ideal. There does not exist at the present time agreement as to the standard or ideal which should be adhered to in the show-ring judging of market barrows; there often are observed sharp differences of opinion. One group, represented chiefly by the breeders or producers, holds to the view that the standard should be represented by the barrow which is the most profitable for the farmer to produce; the second group insists that the standard should be based strictly on the pig's fitness to meet the requirements of the packer or consumer. The points of disagreement have to do chiefly with the type or general conformation, and of the condition or degree of finish.

[1] The following set of standard production-registry requirements were adopted by the National Association of Swine Records in 1945:

(a) A sow must farrow and raise a minimum of 8 pigs to a 56-day litterweight of at least 320 pounds; for the gilt 15 months of age or under at farrowing time, the 56-day litterweight will be converted to a sow basis by multiplying by the factor 1.17.

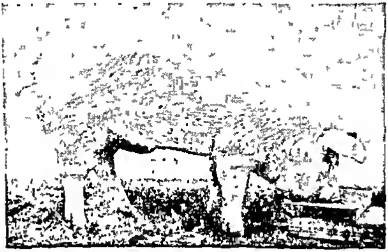
(b) A boar shall become eligible by siring 5 two-star PR daughters, 10 one-star PR daughters, or any combination of one- and two-star PR daughters totaling 10 stars, not more than two of which are full sisters; or when he has sired 15 PR litters from at least 10 different dams, not more than two of which are full sisters.

The intermediate type meets both producer and consumer requirements. Breeders and feeders are disposed to criticize decisions which are based strictly on prospective cut-out value because, it is argued, the packer buyer in his daily practice does not sufficiently discriminate in favor of such hogs in the prices he bids. It must be admitted that so long as market hogs of the same approximate weight sell at the same price, or the usual narrow range of prices, so-called packer requirements will have little influence in determining the type of hog the farmer believes is the most profitable to produce. Producers say that the most profitable type is the one which is most consistent with the ability to produce and raise large litters of pigs which possess the capacity for rapid and economical gains up to a market weight of 180 to 250 pounds. No hogman would seriously dispute this conclusion.

But in view of the fact that it has been demonstrated that the intermediate type is the most efficient in these practical essentials, and since the intermediate type of hog when marketed at the popular weight and carrying the right degree of finish or condition also produces a carcass highly acceptable to the packer, it would appear that there is no real basis for a conflict of opinions between the breeder and packer on the matter of type (see page 118). Although slow-feeding hogs sometimes win in barrow shows and carcass contests, the records show that most have made gains considerably above the average. The carcass contests have had the effect of modifying the breeder's type in only one respect; namely, they have demonstrated the importance of more length of side, and this, if not carried to the extreme, is all for the best from the producer's point of view.

How much fat should the show barrow carry? With respect to the matter of condition or degree of fatness, the carcass contests and research studies have clearly demonstrated that an amount of back fat much in excess of 1.6 inches for a 220-pound market hog, under the price conditions which normally prevail, results in a lower proportion of the high-priced primary cuts and an excess production of the strictly fat cuts and lard; and that an amount much less than 1.5 inches results in a lower value for the carcass, due to a decrease in yield or dressing percentage and an amount of fat insufficient to ensure the desired quality and firmness in the cuts (see page 488). Although corn is our principal hog feed, and admitting that the chief function of the Corn Belt hog is to convert corn into pork, this does not mean that the farmer or breeder can afford to ignore consumer requirements by producing overweight, overfat hogs for the market. However, when

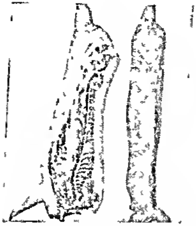
A—The old-fashioned extreme lard type. International grand champion barrow in 1913; too lardy for present market demands.



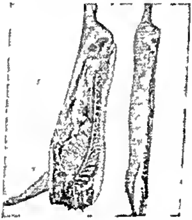
B—The *improved meat type; smooth, firm, trim*; the type and *finish* which produce the quality of cuts in demand. Grand Champion Hoosier Spring Barrow show, 1950.

C—The bacon type. Champion Yorkshire barrow Chicago International, 1950.

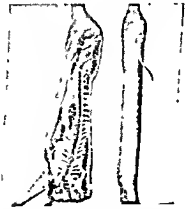
Fig. 76. Types of market barrows.



A—Carcass produced by the old-fashioned extreme lard type.



B—The type of carcass in greatest demand in the United States; produced by the improved intermediate or meat type of hog.



C—Illustrating a good bacon carcass.

Fig. 77. Carcass types *(courtesy, U.S.D.A., Bureau of Animal Industry)*.

he is long on corn and short on number of hogs, he will continue to produce heavy overfat hogs so long as the market discount on this kind is not too severe.

It is on this matter of condition, the degree of finish which the show barrow should carry, that the producer and packer seem to have

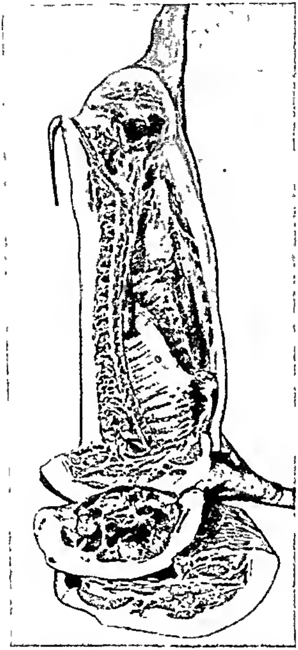


Fig. 78. Grand champion carcass at the 1949 Chicago International, a purebred Berkshire, shown by Milo V. Wolrab, Mt. Vernon, Ia.

a legitimate basis for disagreement. If the chief function of the barrow show is to express, so far as possible, consumer requirements, regardless of any other consideration, decisions must be made strictly on the basis of prospective killing qualities, which usually means sharp discrimination against those which would produce overfat carcasses and those which require wasteful trimming. If, on the other hand, the function of the barrow show is to illustrate the kind which the farmer considers most profitable to produce, considering consumer demands

only to the extent that they are expressed in live-hog market prices, then the show-ring decisions will be less critical of an overfat condition and, perhaps, also of wasty underlines and a general lack of firmness, even though this extra fat represents a waste of feed and further additions to the lard surplus.

A suggested compromise. A reasonable compromise between these two parties of the industry would seem to be a standard which adheres fairly closely to the principle that the barrow show's first duty is to familiarize the producer with the packer and consumer needs, but which at the same time makes some concession to the feeder's and breeder's point of view by accepting a little more fat than is needed to produce a Choice No. 1 carcass. Probably some consideration also should be given by the barrow judge to the legs and pasterns and certain other features which contribute to "eye appeal," such as the hair coat, style, and general attractiveness.

The score card. The score card is the result of the efforts of the livestock judge to describe in detail the perfect animal. In addition, the effort is made to assign to each detail a value which correctly indicates its importance when considered in relation to the other details and to the animal as a whole. The arrangement of the score card is such that a systematic and detailed examination of the animal is facilitated. Blank spaces are usually provided in which the scorer may record his ratings for the different "points" or details.

The score card method of selecting animals or of judging groups or classes is not a practical one, owing chiefly to the time required. Its general use is impracticable also because few are sufficiently expert in its used to do consistently accurate work with it. But the fundamental reason why the score-card result must always be subject to review is because a given "point" may be so faulty that its importance in relation to the individual as a whole is enhanced far beyond the number of credit points assigned to it by the score card. As an expression of a standard of perfection and as a means of preliminary study, however, the score card has proved itself of great value in teaching the rudiments of livestock judging to the beginner.

Discussion of the score card points of the market barrow.

1. *Weight* (4 percent). The age of the pig must be considered when scoring the weight. Although the market usually prefers a weight of 200 to 225 pounds, from the producer's or show-ring standpoint the heavier a pig is for his age, the better. If he has made a gain from birth

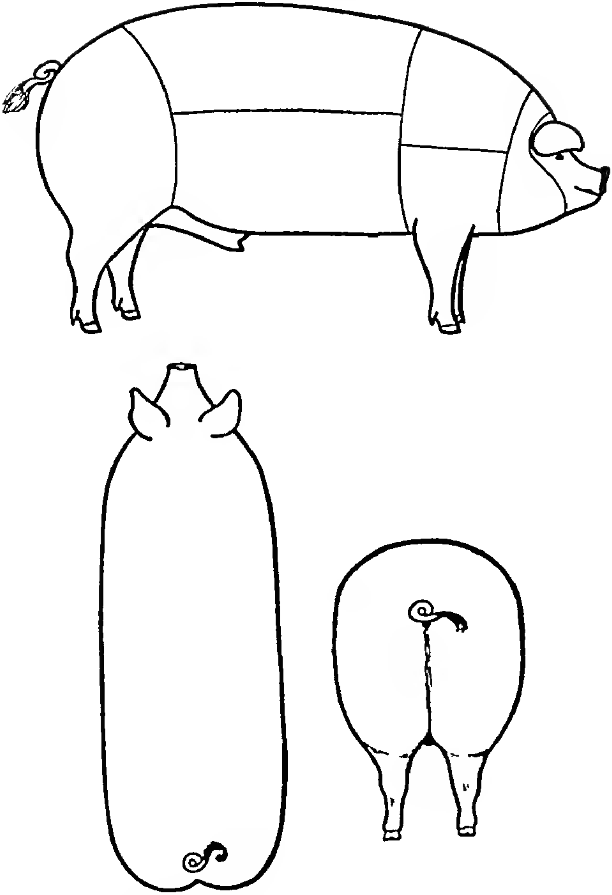


Fig. 79. Side, top, and rear views of a model market barrow.

Score Card for Market Barrows

Scale of Points	*Standard, or Perfect Score*
GENERAL APPEARANCE—30 PERCENT	
1. *Weight.*—Score according to age	4
2. *Form.*—Deep, fairly broad, long; evenly arched top line; trim, straight underline; compact, symmetrical; standing squarely on straight legs of medium length	10
3. *Condition.*—Well finished; even, firm, yet mellow covering; free from rolls and flabbiness	10
4. *Quality.*—Hair smooth and fine; bone of medium size, clean, and hard; smooth, refined general appearance; free from creases and wrinkles	6
HEAD AND NECK—8 PERCENT	
5. *Snout.*—Medium length, not coarse	1
6. *Eyes.*—Prominent, clear, not obscured by wrinkles	1
7. *Face.*—Clean-cut; cheeks full	1
8. *Ears.*—Medium size, attached neatly	1
9. *Jowl.*—Neat, firm, free from wrinkles	2
10. *Neck.*—Short, full, smooth to shoulders	2
FOREQUARTERS—14 PERCENT	
11. *Shoulders.*—Deep, smooth, compact on top	10
12. *Breast.*—Full, smooth, neat	2
13. *Legs.*—Straight, medium length, strong; bone clean, hard; pasterns strong, straight; feet medium size, toes together	2
BODY—33 PERCENT	
14. *Chest.*—Full back of shoulders, wide, deep	4
15. *Sides.*—Deep, good length, straight, smooth	8
16. *Back.*—Fairly broad, uniform in width, strongly arched; thickly and evenly covered	9
17. *Loin.*—Thick, strong, same width as back	7
18. *Belly.*—Straight, smooth, firm	5
HIND QUARTERS—15 PERCENT	
19. *Rump.*—Long, not steep, wide, evenly fleshed	4
20. *Ham.*—Full, deep, wide, firm	9
21. *Legs.*—Straight, medium length, strong; bone clean, hard; pasterns strong, straight; feet medium size, toes together	2
Total	100

approximately of 1¼ pounds daily he should be given a perfect score.

2. *Form* (10 percent). The ideal form is described briefly in the score card. This type of finished fat barrow is preferred by the packer

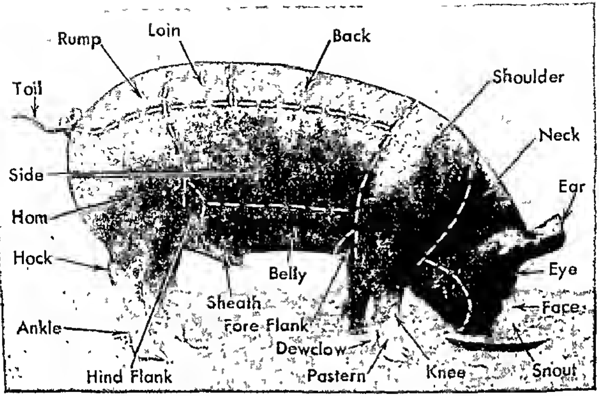


Fig. 80. Showing points of the market barrow.

because it will dress out a large proportion of edible meat to offal and lard, with a high porportion of the so-called primary cuts, hams, loins, bacon, Boston butts, and picnic shoulders.

The common faults in the form of the finished fat barrow are lack of symmetry and uniformity of width, heavy shoulders, wasty middle, and light hams. To the butcher these faults in external appearance mean low dressing percentage, a carcass which is heavy in front and light in the loin and hams, and excessive trimming in the preparation of the cuts for sale.

3. *Condition* (10 percent). Because of the low value of lard and the demand for leaner cuts, less fat is now wanted than formerly in the market hog. Compared with the old standard, he should be moderately finished, with a firm and even fat covering.

The degree of fatness is shown by the general plumpness of the individual, and is generally judged by the width or thickness of the back and loin. Sufficient fat is required to give quality to the cuts, but over-fatness should be sharply discriminated against.

4. *Quality* (6 percent). The finished barrow should show quality in every line and feature. His hair coat should be fine, straight, and lie close to the body. The bone should be of medium size, clean, and hard in appearance. The head should be light, the features clean-cut, and

the ears fine. The skin should be soft and healthy and there should be no evidence of general roughness, creases, or wrinkles along the shoulder sides and sides.

Quality is important in the market barrow because quality on foot indicates fine texture in the meat. It is important also because he can be more easily dressed, his yield will be somewhat greater, and less trimming will be necessary in shaping up the various carcass cuts.

5. *Head and Neck* (8 percent). The butcher is interested in the head and neck chiefly because it is cheap meat and mostly waste. The less the weight and more refined the features, therefore, the better.

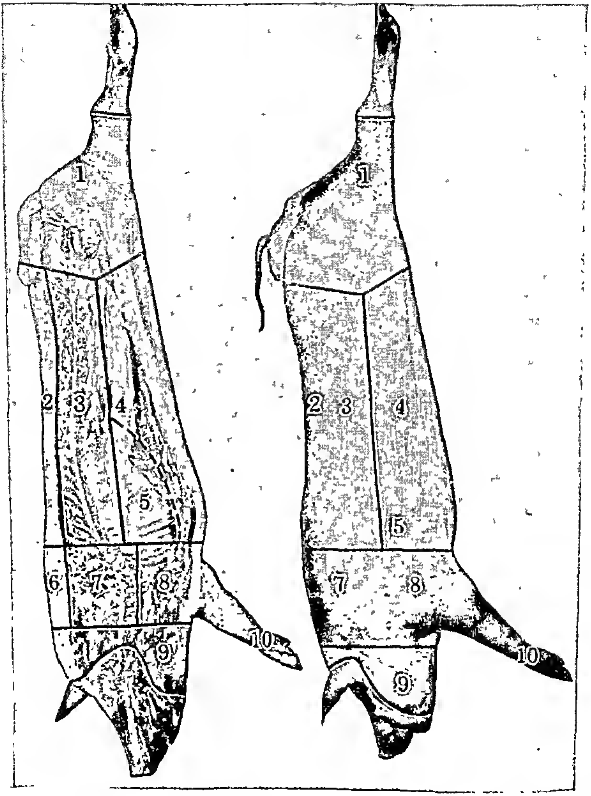
6. *Fore Quarters* (14 percent). The shoulders represent the largest part of the fore quarters. This is indicated on the score card by the large credit of eight points given them. It is particularly important that they be smooth and compact on top, join smoothly with the neck and sides, and be free from any tendency to roughness or creases along the sides. They should be deep also and the breast full and the legs wide apart.

7. *Body* (33 percent). All parts of the body are important to the butcher because together they represent the largest part of the salable carcass. A fairly broad, thick, strong back and loin, deep, smooth sides, and a trim, straight underline are the features most desired. The most common and serious faults are a heavy paunch and wasty underline, "fish" back, weak loin, and creases along the sides.

8. *Hind Quarters* (15 percent). The hams represent the principal part of the hind quarters. The rump is part of the ham cut. The width of the rump and the thickness of the hams should be the same as the width of the back and loin. The hams should not be soft and baggy, but long, full, deep, and muscular. They should also be broad and wide and well covered in the region of the stifles.

JUDGING SOWS AND BOARS

The score-card description of the mature sow attempts to describe in detail the ideal. This is an individual of the improved intermediate type, which belongs to no particular breed, a little larger in size than most farmers want. It is a model obtained by combining in one individual the desirable qualities of all our common breeds, irrespective of color and other breed-type features.



1. Ham
2. *Fat back*
3. Loin
4. Bacon
5. Spare ribs
6. *Clear plate*
7. Boston butt } shoulder
8. Picnic shoulder } shoulder
9. Jowl
10. *Foot*

Fig. 81. Standard cut of pork, Chicago style *(courtesy Ill. Exp. Sta.)*.

Score Card for the Brood Sow

Scale of Points	*Standard, or Perfect Score*
1. *Size.*—Score according to condition and age	10
2. *Head.*—Wide between the eyes; face moderately dished, medium in length, refined; typical of the breed	4
3. *Eyes.*—Large, prominent, clear	2
4. *Ears.*—Medium size, strong knuckles; not coarse; typical of the breed	2
5. *Neck.*—Full, slightly arched, medium length, free from creases; blending smoothly with the shoulders	2
6. *Jowl.*—Full, firm, smooth, neat; not flabby, coarse, or wrinkled	2
7. *Shoulders.*—Compact, smooth, deep; blending smoothly with the back and sides, well covered	6
8. *Chest or Heart Girth.*—Deep, full, large girth	7
9. *Back and Loin.*—Strong, evenly arched; high, square-sprung ribs; fairly wide, uniform width; smooth, firm covering	13
10. *Sides.*—Long, deep, straight with shoulders and hams; smooth, free from creases or wrinkles	8
11. *Belly and flanks.*—Belly broad, full, neat; a minimum of five prominent, evenly placed teats each side; flanks low and full	10
12. *Rump and Hams.*—Rump wide, same width as back and loin, long, full, rounding, sloping gradually from loin to tail; hams deep, wide, thick, firm, muscular, smooth; stifles well covered; junction of hams low and full	8
13. *Legs, Pasterns, and Feet.*—Legs medium length, straight and set squarely; bone large, clean-cut; pasterns straight, nearly upright, strong; toes together, short, squarely placed	10
14. *Tail.*—Medium size and length, nicely curled, indicative of size with quality	1
15. *Coat.*—Fine, straight, thick, smooth, glossy, lying close to the body, evenly distributed, free from swirls; color typical of the breed	3
16. *Skin.*—Healthy, soft, smooth, free from excessive scurf	2
17. *Action and Style.*—Action free and easy, legs carried straight forward; attractive carriage	3
18. *Disposition.*—Easy to handle, gentle, active, lively	3
19. *Symmetry or Balance of Points*	4
Total	100

By making the following substitutions or changes, the above score card may be used for the boar:

2. *Head.*—Wide between the eyes; face moderately dished, medium in length; strong and masculine	4

5. *Neck*.—Full, slightly arched, short, strong, free from creases; blending smoothly with the shoulders	2
11. *Belly and Flanks*.—Belly broad, full, trim; rudimentaries numerous and prominent; flanks low and full	5
20. *Testicles*.—Medium and uniform in size; symmetrically carried	3

Discussion of the general points of the brood sow.

In practical judging, the details of the brood-sow score card may be grouped appropriately under the following general heads:

1. *Size* (15 percent). The size should be judged according to the age and condition of the individual. Mature sows in breeding condition should weigh about 500 to 600 pounds, and mature boars 600 to 700 pounds. Sows 18 months old in good breeding condition should weigh 425 to 450 pounds, and boars 500 to 550 pounds. A good standard for gilts and boars 12 months old in thrifty, growing condition is a weight of 350 to 400 pounds. Mature sows and boars in show condition usually weigh 150 to 200 pounds more than in breeding condition, and yearling sows and boars about 100 pounds more.

Breeding animals should be of good size because the ability of the pig to make rapid gains is determined very largely by the size of its parents. Within reasonable limits, the larger the parents the faster the gaining capacity of the pig. This is the justification of the 500-pound sow in the face of a market demand for a 225-pound pig.

2. *Form* (40 percent). The form also should be judged according to the age and condition of the individual. The body should be deep and of good length; the back should be strong and well arched, the line of arch being regular from neck to tail; the flanks should be low and full, and the length of leg medium. The shoulders should be smooth and compact; the back and loin fairly broad, showing good spring of rib. There should be great uniformity of width from the front of the shoulders clear back to the base of the hams, along the middle and bottom line as well as at the top. The heart girth should be full and the sides straight and even; the hams should be long, deep, wide, and thick. The head and snout should be broad and the face of medium length. The eyes should be large, prominent, and clear; the neck short and full and joining smoothly with the shoulders on the top and along the sides. All these parts should be joined together in a manner to give great symmetry and smoothness of form.

The ideal type or form of the brood sow is the one which best qualifies her for the work she has to do. The form here described is

one which permits of regular breeding habits and at the same time ensures constitution and feeding capacity in the pigs and their ability to top the market when sold to the butcher.

3. *Feet and Legs* (15 percent). In the mature sow and boar the legs should be of medium length, neither too short nor too long. Pigs should appear a trifle more upstanding. The bone should not be fine but medium to large in size, and clean-cut, hard, and strong in appearance. The legs should be straight viewed from the side, front, or rear, attached squarely at each corner of the body, and particularly strong at the hocks, knees, and pasterns. Any tendency to knuckling over at the ankles or of crampiness should be regarded as very serious. The pasterns should be short and the feet strongly and symmetrically shaped.

Breeders who select for fine bone in their hogs usually lose size, constitution, and general ruggedness. And, on the other hand, those who value heavy bone as a merit in itself are in danger of sacrificing quality, smoothness, and early maturity. Since the ideal hog must have size with quality, and ruggedness with smoothness and early maturity, the wise course for the breeder to pursue would seem to be one which lies between these two extremes.

4. *Condition* (10 percent). Show standards place a premium on high condition regardless of the fact that injury to the breeding functions frequently results. The exhibitor should endeavor to meet this standard only in so far as it is not permanently detrimental to regular breeding performance. The fat covering should be uniform in its depth all over the top from the shoulders back to the tail and down along the sides. There should be no tendency to bareness in the region of the rump and loin, or to rolls along the foreribs or back. The covering should be firm to the touch on top, and there should be no excessive softness or flabbiness in the jowl, along the lower lines and hams. High condition is to the credit of the individual only when the fat covering is smooth and firm and the weight is carried with ease and freedom. The judge is justified in discriminating sharply against excessive fatness as shown by lack of smoothness, extreme softness, and general inability to move about with ease.

5. *Quality and Smoothness* (10 percent). The indications of quality are the same in the brood sow as in the fat barrow. The sow or boar whether in thin or fat condition should have a smooth, fine coat of hair. Swirls are a disqualification. There should be complete absence of any tendency to deep creases, wrinkles, coarse or unhealthy skin.

Excessive development of shields in the boar is objectionable. There should be no evidence of coarseness or grossness of features about the head, the face should be clean, the ears neat, and the jowl light. The bone should be clean and hard looking. A little more general refinement is wanted in the sow than in the boar.

Quality is desired in breeding stock because of the relation it bears to early maturity and killing qualities of the finished market pig. Early maturity means the ability to fatten and be ready for market at a comparatively early age. The degree of early maturity wanted is that which is just sufficient to guarantee a finished market condition without overfatness when the pigs are 6 to 8 months of age.

Quality must not be insisted on, however, to the point of sacrificing size and growthiness. The tendency to do this is not so common now, however, as formerly. It seems to be much easier for the breeder to secure and maintain a high degree of quality than it does size. Although it is difficult to maintain ample size in itself, to do this and at the same time retain sufficient quality is more difficult still, but possible. At any rate, this is the ideal for which all breeders are striving.

6. *Sex Characteristics and Disposition* (10 percent). It is very desirable that the sow be feminine and breedy in appearance. This is shown by strong development of 10 to 12 well-placed teats, good length and depth of side, refinement of features about the head and neck, and rather light shoulders. The boar, on the other hand, should be strong and masculine, possess normally developed sex organs, prominent rudimentaries, and strength in the head and neck. Good development of the characters associated with sex is believed by breeders to ensure fertile, reliable breeding traits.

It is a matter of considerable importance that the sow and boar be of good disposition. They should be mild and quiet rather than nervous, irritable, or cross. Also, they should be active and vigorous rather than sluggish, awkward, or unduly lazy. A good disposition is associated with the best feeding qualities as well as being an important factor in the number of pigs which the sow raises.

JUDGING GILTS AND YOUNG BOARS

In judging young boars and gilts, it is important that they be considered as prospective breeders rather than according to the standards of type required of mature individuals or finished fat barrows. The type of gilt should be preferred which gives promise by her size and

form to develop into a large, smooth, roomy sow at maturity. To obtain this type the mistake should not be made of selecting the short, thick, fine-boned kind. The short, chubby gilt which possesses the form and finish of a mature sow rarely develops into the type the breeder desires. To obtain the kind which will grow out well, preference should be given to those which appear a trifle leggy, compared with the type at maturity, and which are large for their age. It is of special importance that they be strong in the back, of good length, possess the required number of prominent well-placed teats, and be squarely placed on straight legs of ample bone. With these, all the depth and quality possible should be sought.

"Blind" teats are inherited. In selecting gilts special attention should be given to the number and placement (distribution pattern) of sound teats. The ideal is six prominent nipples on each side, with equal distances between the respective pairs, and with the first, or front, pair well forward. It is surprising how few in a herd will meet this standard.

Studies by Wentworth,[2] involving 57 grade Duroc sows and 510 pigs, showed a distinct tendency for the number of pairs of mammae to be inherited. Nordby of the Idaho Station[3] from his studies of congenital defects in the mammae of swine concluded that inverted nipples (blind teats) obviously were inherited, probably as a recessive. He also determined that inverted nipples could not be extended by manipulations. According to Weaver and Bogart of the Missouri Station[4] the number of blind, or inverted, teats can be determined at birth with an error of less than 5 percent.

In general these studies and observation suggest that the number and distribution of the rudimentaries of the boar are just as important as the number and distribution in the gilt, in affecting the nursing quality of their daughters. This fact is most important in selecting or judging young boar pigs.

JUDGING FEEDERS

The most important point in the selection of feeder pigs is to get them healthy, vigorous, and free of parasite infestation or contagious disease. Pigs which cough much, have rough coats or mattery eyes, or are gaunt and listless in appearance should be looked on with suspicion. A knowledge of the conditions of sanitation and methods of

[2] E. N. Wentworth, *American Naturalist*, Vol. 47, 1913.
[3] Julius E. Nordby, *Jr. of Heredity*, Vol. 25, 1934.
[4] L. A. Weaver and Ralph Bogart, Bul. 461, 1943.

feeding employed on the farm where the pigs were produced is necessary in order to judge accurately their probable health and feeding qualities.

A second important point is to get the pigs as uniform as possible in age, weight, condition, previous feeding, color, and type. Similarity of color usually means similarity of breeding and hence uniformity in the resulting features of type and early maturity. A load of pigs uniform in age, condition, and method of previous feeding will feed more uniformly, reach market weight and finish more nearly at the same time, and will sell more satisfactorily when placed on the market.

The ability of a pig to make rapid gains is largely influenced by his form or type. Also, his appearance when finished for market may be predicted by that when thin. He should possess the same essentials of good conformation demanded of the pig intended for the breeding herd, with emphasis on those features which denote vigor and feeding capacity. He should be broad at the poll, wide between the eyes, with a face of medium length. A narrow head and long sharp nose are not associated with either good feeding or good killing qualities. He should be strong-backed, wide in his spring of rib, and show plenty of capacity of middle. A full heart girth and low flanks are indications of constitution and gaining ability which should not be overlooked. It is of special importance also that he be good in his legs and feet; that is, they should be medium in length, squarely set, straight and strong.

Condition, or degree of fatness, is an important point in judging feeders. The most satisfactory feeders, as a rule, are those which are well grown for their weight, or in other words, are in a thrifty growing condition rather than fat. Pigs which have been grain-fed in dry lots do not gain as well as those which have been grown largely on forage. Forage-fed pigs are usually thinner, have more "stretch," are glossier of coat, and more healthy than pen-fed pigs.

In weight, feeder pigs usually range from 65 to 150 pounds, and in age from 3 to 8 months. There seems to be no best weight or age, although the heavier and older the pigs are, the shorter will be the time required to get them to market condition. Although the lighter pigs require a longer feed and do not make such rapid gains, they make more gain from a given unit of feed consumed. For following cattle, the heavier pigs are more suitable.

As much quality should be secured as possible, provided general vigor and constitution are not sacrificed. Quality in feeder pigs will ensure a finished condition when market weights are reached and will do much to help sell them when ready to ship.

XX *Breeds of Hogs*

Practically all of the more popular breeds of swine in the United States today have been developed in this country. The Berkshire and the two bacon breeds, the Yorkshire and Tamworth, are the only exceptions. This is interesting in view of the fact none of our major breeds of cattle or sheep and few of our breeds of horses were American born. During the period of early breed development in this country, from 1800 to 1880, the type of hog demanded by the pioneer farmer was one which was hardy, able to travel long distances, possessed of large capacity to consume corn and mast, and with the ability to furnish thick, heavy cuts of pork when marketed. The European breeds did not seem to meet these requirements.

Foundation of our American breeds. Our American breeds, however, were not developed without recourse to foreign stock. They descend wholly from the importations made during the early periods of American history plus extensive additions from 1800 to 1850. There were no native wild hogs on the continent to furnish a foundation. The "razor-back" is a descendant, gone wild, of hogs imported mainly by the early Spanish explorers.[1] It is the conclusion of John Ashton,[2] based on research studies, that the American Indian first tasted pork in December, 1540 when DeSoto invited the chief of the Chickasaws and his principal men to feast and "gave them hog's flesh to eat."

large, coarse hog that was heavy in the ear and bone, to the small, fine-haired, early-maturing kind. The stock which originally came from China, Siam, and Italy was of the latter type.

From this conglomerate mixture our American breeds were developed by selection; some of them exhibiting more of the characteristics of the large, coarse kind, and others a preponderance of the fine-boned, delicate-fleshed, early-maturing type. Incidentally, also, the great variety of genetic qualities contained in the foundation stock is what made possible those radical type changes which we witnessed in most of our breeds from 1910 to 1925.

POLAND CHINA[3]

The early Poland China was developed chiefly in the Miami valley in Warren and Butler counties in southwestern Ohio during the period from 1800 to 1850. This was the richest corn-producing area of the time and enjoyed the advantage of being located in close proximity to Cincinnati, the pork-packing metropolis of America prior to the Civil War.

The hogs brought into this district by the early settlers from the eastern states were mixed in color, breeding, and type. This stock was modified by the introduction, around 1816, of the Russian hog, the Byfield, and the Big China, all of which were white in color. The result of these infusions, with selection, was a hog that became widely and favorably known as the Warren County Hog. The Berkshire was introduced in some numbers from 1835 to 1839, its influence resulting in a hog of mixed black and white color, and improved quality, symmetry, and early maturity. In 1839 three head of superior hogs, known as Irish Graziers, were imported from Ireland. It is generally understood that no outside blood has been introduced since 1845.

Breeders who contributed most to the early improvement of the breed and who established herds between 1816 and 1840 were the Shakers Society of Union Village, a communistic sect, D. M. Magie of Oxford, John Harkrader of Springboro, and James Duffield of Somerville, all of Ohio.

The present color of black with six white points did not become

[3] In the preparation of this chapter the author has drawn heavily from Vaughan's *Breeds of Live Stock in America*, 1946, published by R. C. Adams and Co., and Briggs' *Modern Breeds of Livestock*, 1949, published by The Macmillan Company. For a much more complete history than is given here, the reader is referred to these texts. Other books consulted were: *Types and Breeds of Farm Animals*, 1920, by C. S. Plumb and *Swine in America*, 1909, by F. D. Coburn.

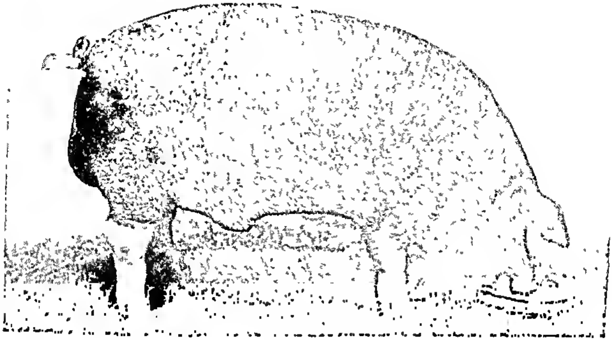
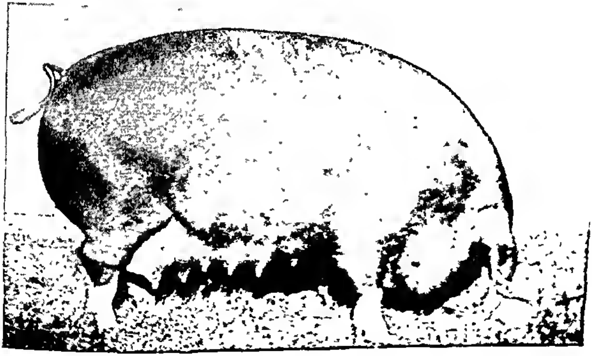


Fig. 82. A Poland China senior spring boar pig which illustrates the type, substance, and quality desired in a future herd sire. Owned by Floyd Friedow, Kanawha, Iowa *(photo by Smith)*.



provement was in the direction of increased quality, refinement, and early maturity. This culminated in the "hot-blood" craze from 1900 to 1910, to be followed later by the fad for the "big-types." From 1915 to 1925 breeders' selections were dominated chiefly by the desire for great size. Since then the trend has been in the direction of a more conservative type, one which is less extreme in its rangy proportions and possessed of more thickness, smoothness, and easy feeding qualities, namely, the intermediate type (see Fig. 75).

SPOTTED POLAND CHINA

Prior to 1880 most of the herds of Poland Chinas were spotted or mixed black and white in color. Even after the adoption of the standard of black with six white points, many farmer breeders, particularly in Indiana, continued to favor the spotted hog. These spotted hogs had a reputation for ruggedness, bone, and prolificacy which attracted

Fig. 84. Spotted Poland China boar Fashion Plate, grand champion at the Illinois and Indiana State Fairs in 1949. Owned by Arnold Moore, Walcottville, Ind. *(photo by Moore)*.

the attention of pork producers and resulted later in the breed organization. The present spotted Poland descends from this foundation, modified subsequently by liberal infusions of the so-called big-type Poland. An importation from England in 1914 of a pair of Gloucester Old Spots added a dash of variety but did not prove popular ulti-

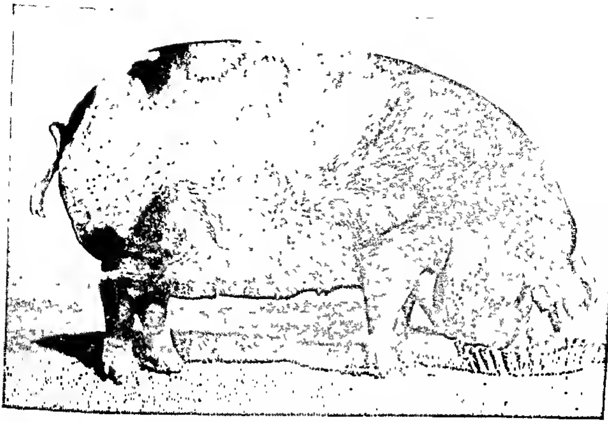


Fig. 85. First prize senior yearling Spotted Poland China sow at Topeka, 1931. Shown by M. C. Scott, La Monte, Mo. *(photo by Smith).*

mately. The official beginning of the breed was the organization of the National Spotted Poland China Record Association at Indianapolis in January, 1914.

The color desired in the Spotted Poland is spotted black and white, 50 percent each. In addition to descending from animals already recorded, eligibility for registration now requires not less than 20 percent nor more than 80 percent of white on the body, not including head and legs. Although one of the younger American breeds, it is well distributed throughout the Corn Belt. Its rapid increase in numbers during the past 25 years especially has been due chiefly to the success of its breeders in preserving the virtues of the old Spotted Poland as expressed in utility standards and to the improvement of the old type in quality and smoothness.

DUROC JERSEY

There is considerable uncertainty concerning the exact elements which composed the foundation stock of the Duroc Jersey breed. It is reasonably certain, however, that it consisted principally of a fusion of the so-called Jersey Red of New Jersey and the Durocs of New York. The Jersey Reds were large, vigorous, and prolific; the Durocs

Fig. 86. Duroc Jersey boar Hid-O-W Deluxe, first prize junior yearling Ill. State Fair, 1949. Shown by W. W. Stock Farm, Pittsfield, Ill. *(photo by Moore).*

Fig. 87. Senior yearling Duroc Jersey sow Proud Fancy, grand champion at the Iowa State Fair in 1949. Shown by Gregor F. Baske & Sons, Dyersville, Iowa *(photo by Smith).*

were more compact, of medium size, and possessed of considerable quality. The sandy or red Berkshire of Connecticut also contributed a small part to the foundation. It is believed that these strains of red

hogs descended from importations of red Guinea hogs from Africa, made as early as 1804, the Spanish red hogs from Spain, and the red Portuguese breed from Portugal. Beginning about 1860 these red hogs were systematically blended. Colonel F. D. Curtis of Saratoga County and William H. Holmes of Washington County, New York, are given credit for furnishing the leadership which organized the eastern breeders and resulted in the adoption of a standard in 1877. Not until the breed moved into the Corn Belt did it come to its own, however. It was here, beginning about 1880, that the modern Duroc was developed.

Breeders who were prominently identified with the early development of the breed in the Middle West were Thomas Bennett and J. M. Browning of Illinois; William H. Holmes and William Roberts of Iowa; Sam E. Morton and C. E. Mahan of Ohio; Carl Scott of Indiana and Amos W. Harris and Son of Kentucky. Somewhat later and beginning about in 1900, the following were leading breeders and showmen: Ira Jackson, Watt and Foust, and Mahan Bros., of Ohio; Ed. M. Kern, John Bader, and Wm. Moderow of Nebraska; McKee Brothers of Kentucky; and S. H. Stanberry and Sons of Tennessee.

According to breed registration figures Duroc Jerseys now outnumber any other breed. This popularity has resulted from the valuable combination of large size with feeding capacity and ability to reproduce. These are the qualities which the farmer regards as most important in indicating practical efficiency. The Duroc has had its type changes, as has the Poland China, and these have followed closely the styles set by the Poland. At present, breeders are selecting for the intermediate type.

CHESTER WHITE

The Chester White had its origin in the fertile agricultural region in extreme southeastern Pennsylvania, mainly in Chester and Delaware counties. The type of hog found here early in the nineteenth century was described as being on the large, coarse order, long-bodied, with dished face, heavy ear and white color, the result "principally of a mixture of the offspring of the English Yorkshire, Lincolnshire, and Cheshire hogs," which had been imported to this district from England by the early settlers.[4] An importation in 1818 by Captain James Jeffries of Chester County of a pair of white pigs from Bedfordshire, England, is said to have exerted a refining influence on the founda-

[4] F. F. Moore, *A Brief History*. Revised. 1929.

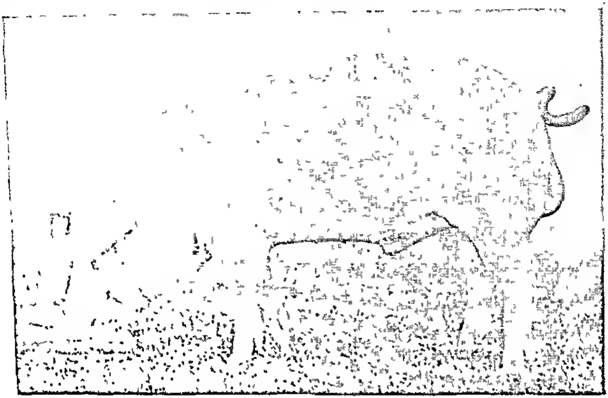


Fig. 88. Tip Top Certified, reserve junior champion Chester White boar pig Indiana State Fair, 1950. Owned by Chester Gullikson, Bath, S. Dak. *(photo by Moore).*

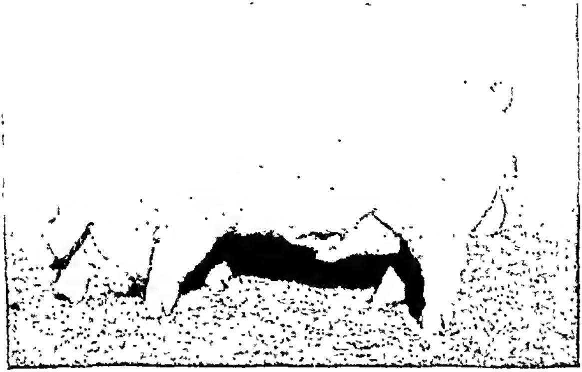


Fig. 89. Alfalfa Toplot 563711, grand champion Chester White boar at the Iowa State Fair in 1949. Shown by Bob Miller, Blanchard, Iowa *(photo by Smith).*

tion stock. At about the same time Harvey Atwood introduced into Delaware County some so-called English China hogs. These were short-legged, broad-backed, heavy-jowled hogs, mostly white in color, with some black or sandy spots. These helped further to reduce the coarseness of the early type and to improve the feeding qualities and early maturity. Other early breeders in Pennsylvania were Benjamin Hickman, Flehalkey Harvey, Thomas Wood, and Strode Brothers. E. B. Ashbridge of West Chester was a leading breeder from 1848 to 1884.

The second phase of the breed's development took place in Ohio, particularly through the work of the Todd family, which began in 1834 and extended over a period of 80 years, Joseph Haskins, George B. Hickman, and L. B. Silver. The strain of hogs developed by the Todd family became known as "Todd's Improved Chester Whites"; those by Silver as "O.I.C.," or Ohio Improved Chester Whites.

The Chester White is one of the most popular breeds in America, with a particularly strong following in the northern Corn Belt states. It has always been a good farmer's hog. The sows produce and raise good-sized litters, the pigs are easy feeders, and the finished fat barrows popular on the market. The breed has made a particularly enviable record in winning grand championship honors in the barrow classes at the International Fat Stock Show. Type changes within the breed have followed in general those of the Poland China and Duroc Jersey, although they were not so extreme.

HAMPSHIRE

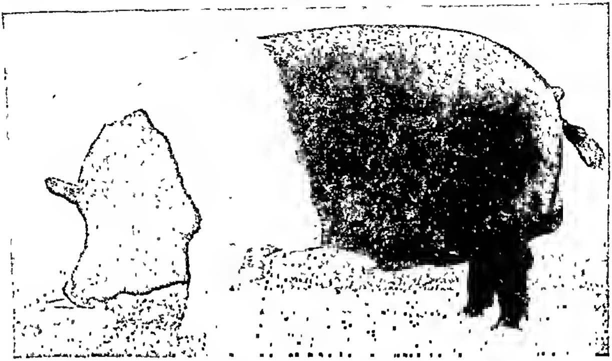


Fig. 90. Master Model, 1949 grand champion Hampshire boar Iowa and Illinois State Fairs. Shown by Model Farms, Mundelein, Ill. *(photo by Moore).*

Fig. 91. Ideal Model Diana 1st, aged Hampshire sow. Grand champion at the Iowa State Fair in 1949. Shown by H. A. Kleemeier, Rockwell City, Iowa *(photo by Smith).*

The Hampshire is one of our younger breeds, but its rise to popularity has been rapid. It is well represented throughout the Corn Belt and in the South. Its striking color gives it an attractive trade-mark. From the beginning the breeders have specialized on quality and

smoothness, and have been less influenced by type fads than have those of some of the other breeds. It is a medium-sized breed, especially noted for its fine hair coat, clean bone, neat jowl, refined head features, and prominent eye. Breeders are now seeking more length of body and fuller hams. The sows have the reputation of raising a very large percentage of their pigs; no breed is more active and none can boast of greater popularity on the market. The breed has made a particularly strong showing in winning grand championship honors in the large barrow shows of the country.

BERKSHIRE

The Berkshire is the oldest of our so-called lard breeds and the only one of English origin. The English historian Culley wrote in 1789

Fig. 92. Grand champion Berkshire boar and leading sire of champions, Epoch's Champ *(courtesy American Berkshire Association)*

that the Berkshires were more numerous than any other pigs in England. They were described at that time as being reddish-brown, with black spots, large drooping ears, short legs, fine bone, and inclined to fatten easily at an early age. Another writer of about the same time said they were large-boned, with turned-up snouts, and some of the specimens very large. On this stock Chinese, Siamese, and Neapolitan blood was used with the effect of reducing size, increasing refinement and the early disposition to fatten. In 1830 they were said to be of a

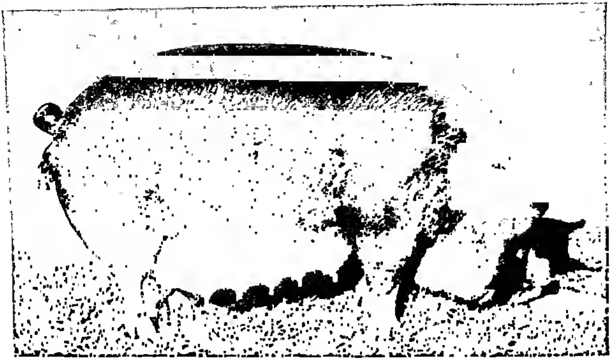


Fig. 93. Aged Berkshire sow, Broadlong Fair Parade, grand champion at the Iowa State Fair, 1949. Shown by Kermit L. Houghen, Radcliff, Iowa *(photo by Smith)*.

sandy or whitish-brown color, spotted regularly with dark brown or black, erect of ear, the head, snout, and legs short, and producers of superior bacon. Most of this improvement took place in Berkshire and neighboring counties in central southern England.

Early importations to America were made by John Brentnall of New Jersey in 1823 and 1832, by Bragg and Waite of New York in 1839, and by A. B. Allen of Buffalo in 1841. By 1835 Berkshires had moved into the Corn Belt and had much to do in influencing the type, quality, and color characteristics of the Warren County hog of the Miami valley, Ohio, progenitors of the Poland China.

Although the Berkshire is of English origin, much, if not most, of its present merit must be credited to the constructive work of the following great breeders of the past generation: N. H. Gentry of Sedalia, Missouri, Snell Brothers of Canada, I. N. Barker of Indiana, and W. E. Spicer and A. J. Lovejoy of Illinois. Most of what is best in the breed today traces to Gentry breeding and the great boar Longfellow, farrowed in 1886.

The Berkshire is not as large as some of the other breeds, but it always weighs heavy for its looks. This is due to the extra length of body and firmness. The carcass contains a very high proportion of lean meat which, with its good length of side, is responsible for the

preference which many American packers have expressed for the breed. No breed is better qualified to meet the present market demand for a meat type of hog. The breed has an enviable record in the production of champion carcasses and in winning highest honors on foot in barrow competitions. The extreme pug nose, which prejudiced many farmers against them in the past, is being eliminated. It is active, hardy, the sows are careful mothers, and the pigs excellent rustlers.

O.I.C.

The O.I.C. Swine Breeders' Association was organized at Cleveland, Ohio in 1897 chiefly for the purpose of registering the strain of

Fig. 94. The O.I.C. boar Royal Monarch, a son of Royal Prince [illegible] Griffith O.I.C. Farms, Greenville, Ill

Both parents must be recorded in order for a pig to be eligible for registration.

The O.I.C.'s as now bred and shown appear fairly distinct in their type and head and ear features from the Chester Whites. They are smaller in size, relatively longer in body, and shorter of leg. Also, O.I.C.'s have a shorter snout, more dish to the face, and heavier ears. As a rule, they lean rather more toward the old-fashioned fat type than to the modern intermediate type. They are prolific, easy feeders, and do especially well in confined quarters.

HEREFORD

Mr. R. U. Webber of LaPlata, Missouri, who began breeding about in 1902, is credited with being the father of the Hereford breed of

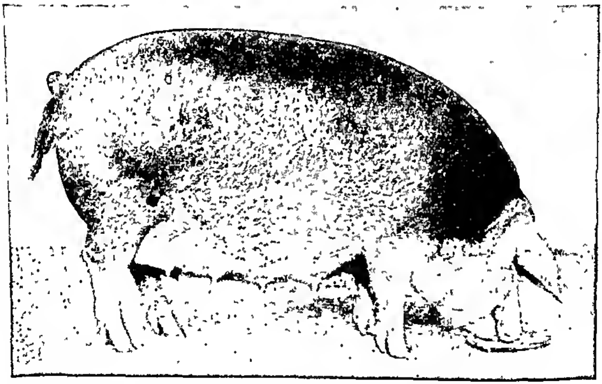


Fig. 95. Hereford sow Cherry Blossom Queen, grand champion at the Iowa State Fair in 1948 (*photo by Smith*).

hogs. According to Webber the foundation consisted of "a cross of the white and red stock of the Duroc, Chester, and O.I.C.'s and a peculiar blood strain." [6] His idea was to create a compact, easy-feeding, quick-maturing type of hog with the color pattern of Hereford cattle.

Early development of the breed was brought about chiefly through the work of John C. Schulte of Norway, Iowa, Leland and Walter

[6] A. J. Way, Sec., *The Origin and Development of the Hereford Hog*, 1940.

YORKSHIRE

This English bacon breed had its origin in Yorkshire and neighboring counties in northern England at an early date. The foundation

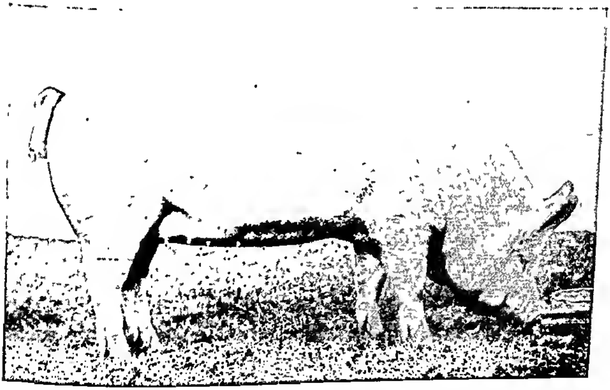


Fig. 96. First prize and junior champion senior Yorkshire gilt, Illinois State Fair, 1950. Shown by Yalehurst Farms, Peoria, Ill. *(photo by Moore).*

stock was composed of large white hogs, with black or bluish spots on the skin, with heavy bone, very large drooping ears, long legs, and narrow backs and loins. This stock was improved by selection and

infusion of the blood of the Leicester pig, a white breed created by Robert Bakewell and noted for its quality and easy feeding traits. In England and most other countries the Yorkshire is known as the Large White. The Middle White is a thicker, shorter bodied hog which was developed in England by the use of Chinese stock on the Yorkshire.

The Yorkshire is generally regarded throughout the world as representing the standards of bacon excellence. No breed appears to be so indispensable in England, Scotland, Ireland, the Scandinavian countries, and Canada, where bacon production for the English market is specialized in. They were imported into the United States at a comparatively early date and now are fairly widely distributed throughout the Corn Belt. They are especially popular in Minnesota, Wisconsin, and Michigan. The trend toward a less lardy hog has caused many farmers to look on them with favor. The Yorkshire produces carcasses of unsurpassed quality and leads all breeds in its ability to raise large litters. Also, according to studies made by Shaw of the University of Saskatchewan[7] the breed leads all others in number of ribs.

The records available indicate greater milk-secreting capacity than is possessed by any other breed. Mated with the right type of boar of any of our American breeds, the Yorkshire sow produces pigs which are excellent feeders and immensely popular with the packer.

TAMWORTH

The Tamworth is also a bacon breed and, like the Yorkshire, was developed in England, although the foundation is said to have come from Ireland in 1812. The original stock was described as being of a dark red color, very lean and active, slow to mature, with very long legs and snouts, and shallow bodies. Improvement was brought about by selection of the foundation material and the introduction at an early date of some Yorkshire and Berkshire blood. The breed seems to have been slow in winning popularity in England, and it was not until about 1880 that its characteristics became fixed by selection.

Tamworths were first introduced into America in 1882 by Thomas Bennett of Illinois, and to Canada, soon after. Although not as numerous as our so-called lard breeds, it is fairly widely distributed throughout the Corn Belt. The breed is especially noted for its smooth shoulders, deep smooth sides, and excellent carcasses. They appear to be longer of leg than the Yorkshire, and not so long of body; the snout is long and the face only slightly dished. The sows are exceptionally

[7] A. M. Shaw, *Sci. Agr.*, Vol. X, No. 1, 1929.

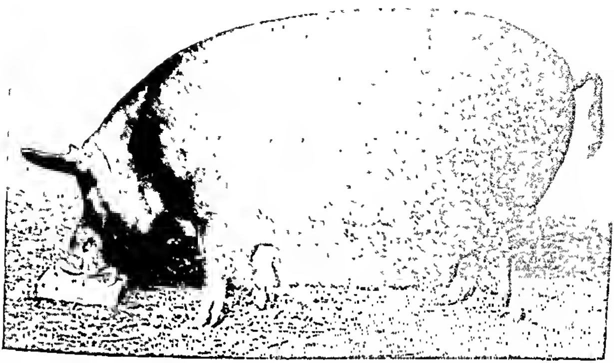


Fig. 97. Senior yearling Tamworth sow Tuscawilla Victory 15th. Grand champion Indiana State Fair, 1950. Owned by Tuscawilla Farm, Hagerstown, Ind. *(courtesy R. H. Waltz), (photo by Moore).*

prolific and the pigs unsurpassed foragers. The color may vary from golden to dark red; numerous black spots as well as curly coats are considered objectionable. The ears should be carried fairly erectly. Swirls disqualify for registration.

SOME NEW BREED CREATIONS

Minnesota No. 1. Practically all of our more common breeds of hogs were developed from foundations representing many diverse types and mixtures of breeding. The Minnesota No. 1 is an exception in that it descends wholly from 14 selected individuals of the Danish Landrace and Tamworth breeds: 8 Tamworth females, 4 Danish Landrace females, and 2 Danish Landrace boars. Only 6 of the original 14, however, contributed to the development of the breed. These original crosses were made in 1936 and 1937 at the North Central Experiment Station of the University of Minnesota under the direction of Dr. L. M. Winters and associates of the University of Minnesota as a coordinated project with the Regional Research Swine Breeding Laboratory.

The goal as stated by Winters [a] was "to combine as much length

[a] L. M. Winters, R. E. Comstock, and D. L. Dailey, "The Development of an Inbred Line of Swine (Minn. No. 1) from a Crossbred Foundation," *Jr. of Agr. Sci.*, Vol. II, No. 2, 1943.

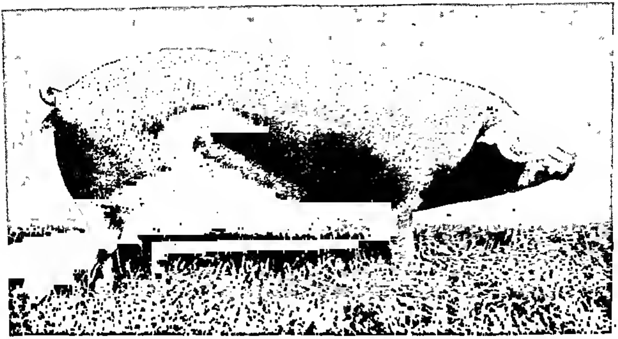


Fig. 98. Minnesota No. 1 gilt *(courtesy Dr. L. M. Winters).*

of body and plumpness of ham of the Landrace with the red color, prolificacy, and milking ability of the Tamworth and at the same time, if possible, bring out through recombination of genes an accumulation of still other desirable characteristics of the two breeds. In this case rapid and economical gains were sought after." The expressed purpose was to produce an inbred line that would prove valuable for crossbreeding.

Following the original cross with a limited number of back crosses subsequently, a program of rather intensive inbreeding with rigid selection for fertility and feed-lot performance was followed for a period of about 6 years. As a result the individuals of the breed, especially those in the foundation herd, are remarkably uniform in their type, color, and performance.

The Inbred Livestock Registry Association was organized in 1946, with L. M. Winters of the University of Minnesota as secretary, for the purpose of registering Minnesota No. 1's and other similar breed creations. To be eligible for registration an individual must be the progeny of a sire and dam which trace their entire ancestry to animals developed and recorded by the University of Minnesota as Minnesota No. 1's, and which possess the individual characteristics typical of the breed.

The Minnesota No. 1 is red in color with some black specks or spots. The body is longer and the legs shorter than in most of our older breeds. The face is only moderately dished, the snout is rather

long, and the jowl very trim. The ears appear large, and droop forward.

Records of the foundation herd give them a high rating in prolificacy, feed-lot performance, and carcass quality. Boars of the breed have been rather extensively and successfully used for crossing on other breeds for the production of market hogs.

Minnesota No. 2. This breed also was developed by Dr. L. M. Winters and associates of the Minnesota Experiment Station as a project of the Regional Research Swine Breeding Laboratory. The foundation consists of the progeny produced by the cross of a superior

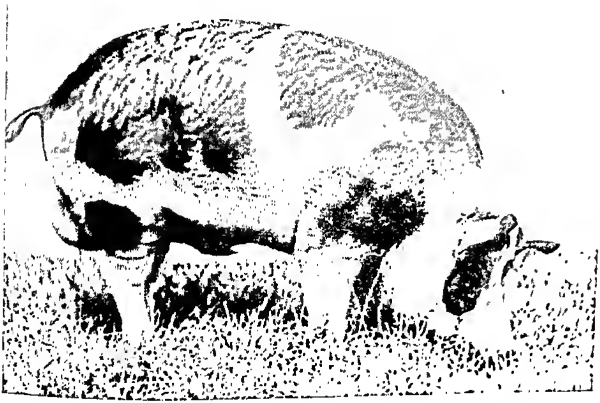


Fig. 99. Minnesota No. 2 boar *(courtesy Dr. L. M. Winters).*

Canadian-bred Yorkshire boar on 13 Poland China sows belonging to two different inbred lines in 1941. By intermating the individuals of the first and second generations, with some back crossing, some desirable combinations of characters were obtained. A program of rather close inbreeding with rigid selection for utility characters was followed thereafter.

The color is black and white. They are longer in leg and larger in size than the Minnesota No. 1's. Also, the face has more dish, the snout is shorter, and the ears are smaller and carried more erectly

Only those individuals that trace their entire ancestry back to the University of Minnesota's foundation herd are eligible for registration in the Inbred Livestock Registry Association.

HAMPRACE (MONTANA NO. 1).

This is a solid black breed developed by Hutton and associates of the Montana Experiment Station and the U.S. Bureau of Animal Industry [9] at the U.S. Range Livestock Experiment Station, Miles City, Montana. The foundation was produced by a cross of two solid black

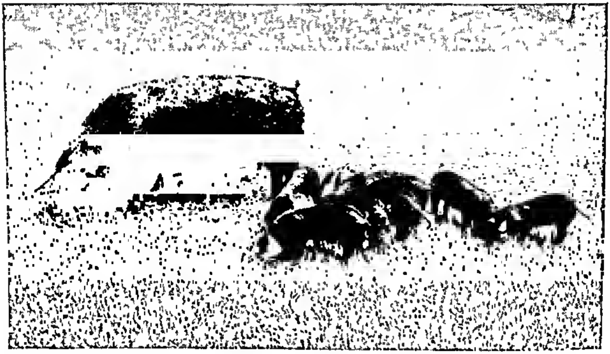


Fig. 100. A Hamprace (Montana No. 1) sow and litter *(courtesy Dr. John H. Zeller and the Bureau of Animal Industry, U.S.D.A.)*.

purebred Hampshire boars on five Danish Landrace sows, and later back-crosses involving one Hampshire boar and five Hampshire sows, and two Landrace boars and five Landrace sows. The original cross was made in 1936.

Following this, a program of rather close inbreeding with selection for a solid black color, prolificacy, good feed-lot performance, and carcass quality was pursued. In 1948 the breed was recognized by the Inbred Livestock Registry Association and registered under the name Montana No. 1. To be eligible for registration animals must have an ancestry all of which trace back to the foundation herd. Animals also may be registered as Hamprace in the Hamprace Swine Breeders'

[9] R. E. Hutton, J. R. Quesenberry, J. H. Zeller, and R. L. Davis, *The Hamprace Hog*, Mont. Agr. Exp. Sta., Bul. 454, 1948.

Association, West Lafayette, Indiana, which was organized in 1950.

SWINE BREED REGISTRY ASSOCIATIONS

Below are listed the swine registry associations in the United States, together with the names of the present (1951) secretaries and their addresses. Also, there is included the number of animals registered by each breed in 1950, as reported by the Breeder's Gazette of March, 1951.

Duroc Jersey. United Duroc Record Association, Duroc Bldg., Peoria 3, Ill.; Sec., B. R. Evans; registrations 121,195.

Hampshire. Hampshire Swine Registry, 1111 Main St., Peoria, Ill.; registrations 72,931.

Spotted Poland China. (a) National Spotted Poland China Record, 3153 Kenwood Ave., Indianapolis 8, Ind.; Sec., Fred L. Obenchain; registrations 47,782. (b) American Spotted Poland China Record, Moberly, Mo.; Sec., Van G. Sutliff; registrations not reported.

Poland China. Poland China Record Association, 501 East Losey St., Galesburg, Ill.; Sec., C. G. McCahan; registrations 32,789.

Chester Whites. (a) Chester White Swine Record Association, Rochester, Ind.; Sec., Levi P. Moore; registrations 25,835. (b) Breeder's Chester White Record Association, Coin, Iowa; Sec., James M. Henderson; registrations approximately 5,000.

Berkshire. American Berkshire Association, 601 W. Monroe St., Springfield, Ill.; Sec., H. L. Brant; registrations 24,793.

O.I.C. (a) OIC Swine Breeder's Association, 112½ S. Main St., Goshen, Ind.; Sec., Harry C. Miller; registrations 15,503. (b) O.I.C. Swine Record Association, Box 373, Rt. 1, Brookville, Ohio; Sec., Jane Roper; registrations not reported.

Yorkshire. American Yorkshire Club, Wallace Bldg., Lafayette, Ind.; Sec., E. Robert Shannon; registrations 15,305.

Hereford. National Hereford Hog Record Association, Chariton, Iowa; Sec., Albert L. Hyzer; registrations 6,898.

Tamworth. Tamworth Swine Association, Hagerstown, Ind., Sec., Ralph H. Waltz; registrations 3,572.

The Inbred Livestock Registry Association, University Farm, St. Paul, Minn.; Sec., Lawrence M. Winters; registrations: Minnesota No. 1, 2,873; Minnesota No. 2, 657; Montana No. 1 (Hamprace) 588.

Hamprace (Montana No. 1). Hamprace Swine Breeder's Association, 907 Vine St., West Lafayette, Ind.; Sec., William H. Yaw; registrations not reported.

Essex. American Essex Swine Association, 1335 East 2nd St., Muscatine, Iowa; Sec., Mrs. J. J. Lighthall; registrations not reported.

Mulefoot. National Mule Foot Hog Record Association, DeGraff, Ohio; Sec., G. C. Kreglow; registrations not reported.

Kentucky Red Berkshire. Kentucky Red Berkshire Swine Record, 303 Stanford St., Lancaster, Ky.; Sec., Hogan Teater; registrations not reported.

XXI *Breeding*

The function of the breeder of purebred hogs is to produce seed stock that will improve the general run of market hogs. Measured by the standard of average merit in our commercial hog supply today, as contrasted with the production of 50 years ago, his contribution has been an impressive one. To make possible a better understanding of the methods employed by the constructive breeders of the past, and possibly to suggest the means available for further improvement, there will be considered briefly in this chapter the facts and principles of reproduction and heredity as now understood and the application or bearing which these facts have on the methods and practices of the breeder and pork producer.

THE LAW OF HEREDITY

The process of reproduction. Every pig has his origin in the union of two germ cells, one produced by the sire and one by the dam. When these two germ cells, male and female, unite, a new individual is born. This process is called fertilization, the successful completion of which marks the real birth of the individual.

The female germ cell is called the egg or ovum (plural, ova), and the male germ cell, the sperm or spermatozoon (plural, spermatozoa). About every three weeks during the breeding seasons the sow, if vigorous and in breeding condition, produces and ripens a number of eggs, usually from 15 to 20. These are produced by special organs, the ovaries, situated in the region of the loin. When the eggs are ripened, they drop into the upper end of the Fallopian tubes and, through gravity and the ciliary motion of the lining membrane cells, finally reach the womb or uterus. The outward manifestations of these functional activities are called "heat."

The male germ-cells or sperm are secreted by the testes, the active part of the testicles, which correspond in function to the ovaries of the sow. For every egg produced by the sow, the boar produces sev-

eral million sperm. Miller of the University of Missouri [1] found when ejaculations were made at intervals of 48 hours or longer, that the semen volume remained above 200 cubic centimeters and the total number of sperm per ejaculate in excess of 20 billion. With more frequent ejaculations, the number of sperm ranged as low as 2.7 billion.

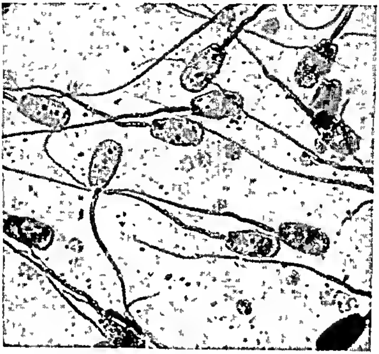


Fig. 101. Spermatazoa of the boar. Magnified 1,200 times *(courtesy Dr. Fred F. McKenzie and Mo. Exp. Sta.).*

The female germ cells are relatively large compared with the male germ cells or sperm. Although too small to be visible to the naked eye, the eggs are several thousand times larger than the sperm. The sperm are extremely minute, measuring $\frac{1}{19}$ of a millimeter in length, which would require that 483 be laid end to end to measure 1 inch. The large size of the egg compared with the sperm does not mean that the sow has a larger influence than the boar in determining the hereditary character of the pig, but only that the food supply (egg yolk) necessary to sustain the life of the fertilized egg until conception has been completed is carried in the egg.

The shape of the egg is spherical, while the sperm is elongated, consisting of a head, middle, and tail piece, very much resembling a tadpole in appearance (see Figs. 101 and 102). While the egg is passive, the live sperm is active and capable of locomotion. This is ac-

[1] James C. Miller, The Reproductive Organs and Semen of the Boar, Phd. Thesis, 1937.

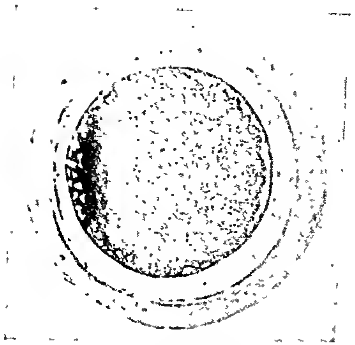


Fig. 102. Egg of the sow, one-cell stage, obtained from sow two days after copulation. Magnified 1,200 times (*Heuser and Streeter,* Contributions to Embryology, *No.* 109, 1929, *Vol.* XX, *Carnegie Institution of Washington).*

complished by the rapid vibrations of its tail-like appendage. There being in a normal breeding service millions of sperm for each egg produced by the sow, the sperm which are most active and get to the eggs first are the ones which fertilize them. Only one sperm ever unites with an egg under normal conditions.

Before the eggs can be fertilized it is necessary for the sperm to travel a distance of 4 to 5 feet. From the uterus or vagina, where the semen is deposited in breeding, the sperm must traverse the uterus, the horns of the uterus, and the greater part of the Fallopian tubes. McKenzie reports that the sperm reach the middle of the Fallopian tubes in about 3 hours after breeding, and the extreme upper end in 5 hours. Since the eggs normally are discharged from the ovaries during the latter end of the heat period (see page 9), the sperm and eggs meet and fertilization is accomplished in the upper portion of the Fallopian tubes.

After the eggs are fertilized they pass down the Fallopian tubes and find permanent lodgment on various areas of the lining membranes of the horns of the uterus. Conception is completed when each egg has taken root, as it were, and established for itself a source of nourishment with the mother. More than a week is required after fertilization for the completion of this important step in reproduction. Cell division or growth begins immediately following fertilization, made possible by the food yolk of the egg and the secretory fluids of the Fallopian

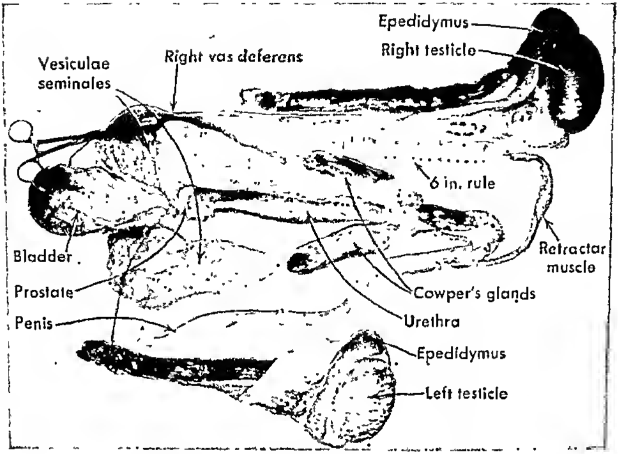


Fig. 103. Genital organs of the boar *(courtesy, Dr. Fred F. McKenzie and James C. Miller and Mo. Exp. Sta.).*

tubes. Each individual egg grows in size and divides into two; each of these in turn absorbs nourishment, grows in size and divides into two, *so that where at first there was the single fertilized egg cell, there are* now four cells. This change, called cell division, underlies all normal growth processes. Following conception, this process of cell division continues until the embryo develops to the point where, in about 114 days after breeding, birth takes place.

Attention has already been given to the fact that no more than two-thirds of the fertilized eggs normally survive to farrowing time. Some probable causes for this heavy mortality during the prenatal life of the pig are discussed in Chapter V, page 117.

"Like begets like." Within each germ cell resides the hereditary material (genes) which is being passed on from parent to offspring. Although these cells are so minute as to be invisible, the extraordinary fact is that they contain every particle of hereditary matter, every influence, which the parents contribute to the unborn pig. The pig inherits nothing which he does not receive in these two germ cells, one supplied by the sire and one by the dam.

When the male and female germ cells unite to form the fertilized egg, there is consequently a union of the hereditary qualities contributed by the boar and sow. Since each germ cell carries a full set of characters (genes), it follows that the fertilized egg, and consequently the new-born pig, is double or dual in nature. In some of his characters the pig may resemble the sire and in others the dam, in some features he may bear an unmistakable resemblance to an ancestor farther back in his pedigree. Speaking in general terms, it may be said that the hereditary makeup of the pig, his color, set of ear, feeding qualities, vigor, and in fact every character, is the result of the combined hereditary influence of his entire ancestry.

This resemblance between the individual pig and his ancestors is a result of the operation of the law of heredity that "like tends to beget like." By this law every living thing reproduces after its own kind and is responsible for the faith which the breeder has in the saying "blood will tell."

Variations. Although prepotent breeding animals transmit their likenesses to their offspring with remarkable faithfulness, it is also true that many and wide variations occur among individuals even of identical breeding or ancestry. This is well illustrated by the variations common among the individual pigs of the same litter, raised together and fed from the same trough. Although heredity impresses or ensures a strong family resemblance, it does not operate in a manner to exclude differences or variations.

Variations among individuals of the same or identical ancestry are of two kinds: first, hereditary variations, and second, variations due to differences in the environment or the conditions under which the individuals were developed.

process of fertilization, following breeding, the chances for variations among the pigs which develop from these eggs are still further magnified. If variations are reasonable among pigs of the same ancestry, it is obvious that pigs of dissimilar parentage, for the same reasons, would normally present even greater variations.

Variations of this kind are of fundamental importance to the breeder because without them selection would be without effect and improvement impossible. It was through the selection of the desirable hereditary variations and their correct combination in mating that all breed improvement has been brought about. Observations of the breeder have shown that some variations are desirable and some undesirable, the larger number being undesirable. There is always the tendency in purebred herds for the offsprings to be inferior to their parents. In other words, pigs produced by prize-winning parents are not so good, on the average, as the parents themselves; a few may be better, but most are inferior. An appreciation of this fact on the part of young breeders will ensure less frequent occurrence of disappointing results.

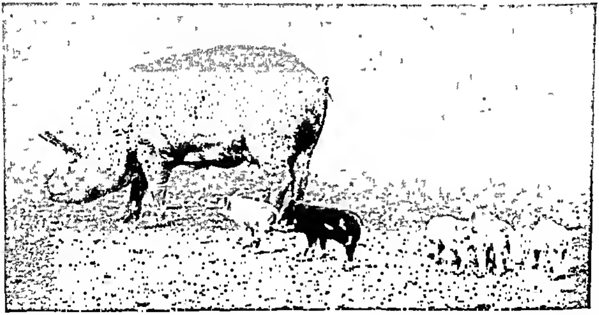


Fig. 104. A crossbred Berkshire-Yorkshire sow with a litter of pigs by a Berkshire-Yorkshire crossbred boar. The color of the black pig represents a reversion.

Variations due to the environment are not inherited. The second kind of variations are those which result from differences in the conditions under which the individuals have been developed. They are sometimes called *acquired characters.* Variations of size and vigor

which result from differences in feeding and care are most common. Two pigs may have an inheritance equally good, but if one is raised in a dry lot on corn and water, while the other has the advantage of balanced rations, a sanitary environment, and plenty of exercise, there will be a marked difference between them at maturity. Likewise, pigs from well-developed parents of the best of breeding if not properly developed will show a wide variation from their sire and dam. These are not due to any difference in inheritance, but rather to the fact that in one case the hereditary possibilities had the chance to develop, while in the other they did not have this opportunity. In order to produce good hogs the breeder must not only produce pigs which possess good inheritance, but he must also give them the conditions which will promote and make possible the full development of these possibilities. In the practical sense, the breeder who is not a good feeder and caretaker cannot succeed.

Variations which result from differences in feeding and management, however, are not transmitted to succeeding generations. The effect of good development on the individual does not improve or change in any way the hereditary content of his germ cells, but is temporary and limited to the individual alone. The importance of good feeding in the development of a young boar is not that he may be able to get pigs which have more size and better feeding qualities, but chiefly to test his own hereditary possibility in this particular. Incidentally he will be a more vigorous breeder and possess an individuality which is an asset to the herd. A boar which has the natural ability to respond to good feeding is more certain to get pigs of this kind than one which did not inherit this capacity. Good development of breeding stock is of fundamental importance, therefore, because it is an aid to more accurate selection.

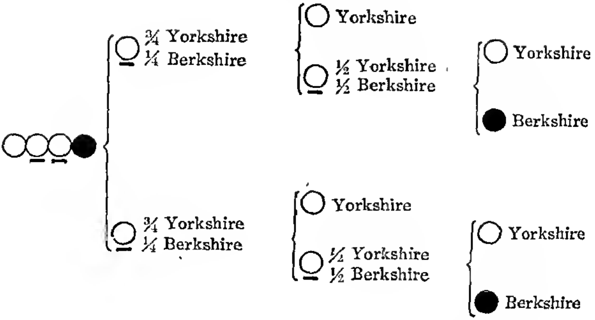


Fig. 105. *Illustrating the principle of reversions.*

In Fig. 104 is shown a white sow with her litter of pigs which includes one black one, a reversion. The sire of these pigs was white like the dam, but both were crossbreds, the result of mating a Berkshire with a Yorkshire. In this instance the black color skipped but one generation. The principle of all variations of this kind is illustrated in Fig. 105.

The original mating in this diagram was a cross between a Berkshire and Yorkshire. Tests show that all pigs produced by such matings will be white like the Yorkshire parent. These crossbred white pigs are then mated with a pure Yorkshire boar, and again all the pigs are white. If these white pigs, which in breeding are considered as three-fourths Yorkshire and one-fourth Berkshire, are now mated to a boar of the same breeding, as illustrated in the diagram, the chances are that some of the pigs will be black. In this case the character black was not expressed in the immediate parents or grandparents, but was shown in two of the eight great grandparents.

The appearance of this black pig, as in the case of all such reversions, does not represent an exception to the law of heredity that "like begets like"; rather it is proof or a guarantee of it. Although the pigs produced by the first Yorkshire-Berkshire mating were all white, so far as their breeding or hereditary quality was concerned they were as much black as white. The black did not show in these crossbred pigs because the white dominated over it. The black, in other words, was present but in a latent or hidden condition, illustrated in the diagram by a dash below the circle. It was present in some of the pigs

also of the next generation, so that in the succeeding generation when two of these white pigs, each with black latent, were mated some of the pigs were black.

What is true of color is true also of the hundreds of other characters making up the individual. A character may be latent or covered up, as it were, for any number of generations and then make its appearance. When two animals are mated each of which has the same character latent, some of the offsprings, if the number of offsprings is sufficiently large, according to the laws of chance, will show the character developed.

Incidentally these facts make plain the important principle that the individual appearance of an animal only partially or imperfectly represents his breeding possibilities. In other words, the individuality of an animal is not altogether a safe criterion of his breeding ability. It also explains why two individuals with exactly the same pedigree may differ materially in breeding qualities. The older a breed, or the more carefully it has been bred within certain lines, the fewer will be the number of latent characters present. Reversions, or the appearance of the unexpected, become less frequent, therefore, in old well-established herds than in those in which outcrossing or crossbreeding has been resorted to.

Prepotency. As understood by the breeder, prepotency is the ability of an animal to impress on his offspring his own characteristics to the exclusion of those of the other parent. It is the ability of the individual to "breed on." Because the sire is more depended on than the dam in livestock improvement, prepotency is sought in the sire rather than in the dam. A prepotent sire is the cornerstone of all herd improvement. It is desirable in the sire used for the production of grade stock and of supreme importance in the head of a pure breed herd.

Observations show that prepotent animals are usually the product of rather close breeding, or, in other words, the result of selecting animals within rather narrow limits of type and pedigree. As shown by experimental studies, the result of such selection is that the germ cells produced by the boar or sow will be more alike in their hereditary qualities and, further, that there will be fewer differences between the hereditary qualities of the sperm on the one hand and the eggs on the other. Pigs resulting from the union of such germ cells will be prepotent when mated with individuals the result of diverse germ cells the result of mixed breeding. Line- and inbreeding have the practical effect, therefore, of intensifying the hereditary qualities and hence of

securing prepotency in the animals so bred. Scrub animals which are the result of scrub ancestry are prepotent in the qualities of the scrub, just as superior specimens are prepotent in their desirable characters.

Relative influence of the sire and dam. As a general rule, it may be said that the sire and dam are equal in the influence which each exerts on the characteristics of the offspring. That is, so far as sex is concerned, they are equal from the standpoint of heredity. As has been seen, the sire contributes a germ cell to the fertilized egg, and the dam furnishes a germ cell. Furthermore, each one of these germ cells contains a complete set of characters (genes) for the new individual. Some of the characters of the sire may dominate those of the dam, and with other characters the reverse may be the case. With many characters, the result is an apparent blend, or intermediate, between the sire on the one hand and the dam on the other. The question whether the black of the boar will dominate the white of the sow is not a matter of sex, but of the character. If one parent is more intensively bred as a result of line- or inbreeding than the other, it will for this reason be more prepotent, independent of any influence of sex.

SYSTEMS OF BREEDING

The two common systems followed in the production of market hogs are upgrading and crossbreeding. A third kind is the one employed in the breeding of purebreds eligible for registration in the records of some breed association.

Upgrading. The quickest, cheapest, and surest method of improving farm herds is by a system of upgrading. It is the method best adapted to those farms which do not already have purebred or pedigreed herds. By upgrading is meant the mating of common grade sows with a purebred boar of the same breed, continuously generation after generation. In effect it means the elimination of the scrub or grade boar. Successful upgrading implies that the purebred boar selected is a good individual and that only the best gilts of each pig crop are retained for breeding.

As illustrated in Fig. 106, the rate of improvement in upgrading is rapid and its results certain. The first cross with a purebred sire produces pigs which are one-half pure. When the gilts of this litter are mated with a purebred sire, the result is a litter three-fourths pure in breeding. The third top cross produces pigs seven-eights purebred, or very high grades, and the next cross is fifteen-sixteenths pure. For feeding and market purposes, the high-grade pig is practically the

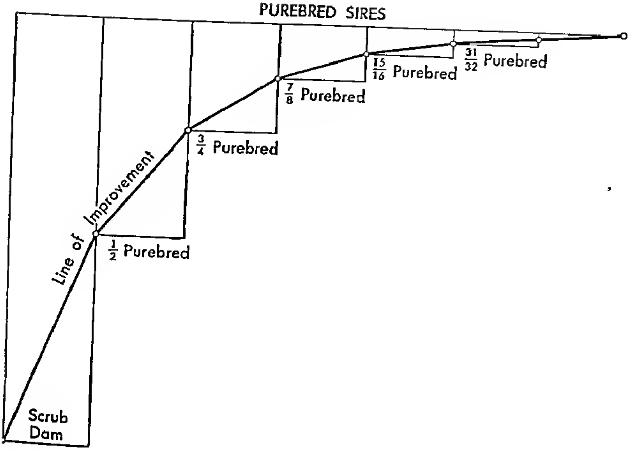


Fig. 106. Showing rate of improvement in upgrading and degree of improvement effected in each generation.

equal of the purebred. For breeding purposes, however, the high-grade boar often proves disappointing.

As illustrated by the diagram, improvement in the upgrading process is at first rapid and then more slow with each succeeding generation. The degree of improvement effected by the first cross with the purebred sire is twice as great as that effected in the second generation; and in the third generation the degree of improvement is only one-half what it was in the second. Improvement in succeeding generations becomes more and more imperceptible as the high-grade females approach in merit and breeding the purebred sires employed. This illustration makes plain the important principle that the more nearly a herd approaches in excellence the ideal, the more difficult does further improvement become. It is easy to improve a mediocre herd, but extremely difficult to better or even to maintain a highly improved one.

Upgrading is economical because the sire mates with the entire female herd and his influence consequently extends to the entire pig crop. The influence of the sow, on the other hand, is limited to a few

Due to the fact that the increased cost of the purebred boar over the scrub or grade boar is thus distributed among a very large number of pigs, the resulting cost of improvement is extremely low. There is no plan or system of breeding so well adapted to the needs of the average farm herd as upgrading.

Crossbreeding. By crossbreeding is generally understood the mating of two purebred individuals which belong to different breeds, as the use of a Poland China boar on Yorkshire sows, or a Hampshire boar on Duroc Jersey sows. The mating of a purebred boar of one breed to grade sows of another breed is also referred to as crossbreeding. Fundamentally, crossbreeding means the mating of individuals of dissimilar type or breeding. In this sense it is correct to speak of crossing one family or strain with another family or strain of the same breed.

Experiments and observation generally have shown that crossbreeding has the effect of increasing somewhat the vigor and feeding qualities. This is known as hybrid vigor or *heterosis*. Another possible advantage is the opportunity which it affords of selecting the sows from a breed and of a type known to be unusually prolific and good milkers and the use on these of boars possessing the type which will ensure sufficient feeding qualities, early maturity, and market qualities in the pigs produced.

Something new in crossbreeding. Attention will be given here to the rather extensive series of crossbreeding experiments which have been conducted by Winters and associates of the Minnesota Station.[2] These began in 1928 and covered a period of 6 years. Records were obtained on 49 different lots composed of 1535 pigs. The experimental data obtained furnish information on farrowing results, the record of the pigs during the nursing period, and the rate and economy of gains from weaning to market, as affected by the following types of matings:

1. *Purebred.* The breeds represented were Poland China, Duroc Jersey, Chester White, and Yorkshire.

2. *First-cross.* These were represented mainly by Poland China × Duroc Jersey, Chester White × Duroc Jersey, and Yorkshire × Duroc Jersey.

3. *Three-breed cross.* These were produced by mating first-cross gilts to a boar of a third breed.

4. *Backcross, or crisscross.* Pigs of this breeding were produced by mating crossbred gilts back to a boar belonging to one of the parental breeds.

[2] L. M. Winters, O. M. Kiser, P. S. Jordan, and W. H. Peters.

Every precaution possible was taken to ensure uniform conditions for the development of these four different lots of pigs. Also, in the selection of the breeding stock, every effort was made to eliminate differences in individuality or breeding.

The essential results as computed and summarized by the authors are shown in Table 173.

Table 173. Summary Advantages of Crossbreds over Purebreds, in Percentages

	First Cross	*Three-breed Cross*	*Backcross or Crisscross*
Birth weight, live pigs	1.96	0.39	14.57
Birth weight per litter, live pigs	13.39	20.65	11.97
Number of live pigs farrowed per litter	11.22	20.19	−2.34
Number of pigs farrowed per litter	4.04	8.62	−11.85
Number of pigs weaned per litter	5.87	36.22	12.21
Live weight at weaning	24.84	60.76	38.89
Economy of gains, or saving in feed	2.99	3.85	2.91
Rate of gain, or saving in time to reach 220 pounds	8.67	8.63	11.28

In the critical points of total weight of the litter at weaning time and the rate and economy of gains from weaning to market time, all three classes of crossbreds excelled the purebreds. Except in economy of gains, the differences were large and consistently shown.

Reviewing the results of the experiment, the authors submitted the following observations and conclusions with respect to their application in market pork production:

"The results obtained from this 6-year experiment have made it very clear that the three types of crossbreds produced are superior for market hog production to purebreds of comparable blood lines. It has been proved very conclusively that the old, rather standard, advice that crossbred sows should all be marketed is erroneous, for the crossbred sows excelled the purebreds as mothers, whether mated to a boar of a third breed or back to one of the breeds that entered in her own breeding. It is, therefore, very clear that there is as much benefit from keeping the crossbred sows for breeding as there is in making the original cross.

"Two opportunities are open to the farmer wishing to use the crossbred sows. One is to mate them to a boar of a third breed, and the second is to backcross them to one of their own two parental breeds. In spite of the fact that the three-breed cross gave the greatest increase in vigor, the authors question the

advisability of this as a general practice, because it is somewhat more complicated when considered from the long-time viewpoint. The backcross presents a rather simple solution of the problem. There is no reason why a farmer cannot continue alternating indefinitely in the use of boars of two breeds. This proposed method of breeding may be labeled 'crisscross breeding.' The pedigree of a pig after four generations of this type of breeding would be as illustrated below.

"The authors suggest that a farmer select two of the popular American breeds of swine, according to his own preferences, and proceed to breed for the market by first using a boar of one breed and then of the other. The same method can be applied to the three-breed cross, by rotating the use of boars of three breeds, but, as already pointed out, this is somewhat more complicated.

"The good purebred sire is the basis for a sound beginning in breeding swine or any other class of livestock for the market. This is equally true of the method of breeding market swine, here proposed. Crossbreeding will not solve any difficulties, or contribute anything to constructive pork production, unless good purebred sires are used. The purebred breeder has nothing to fear from the proposed method of breeding for the market. In fact, he has something to gain, for good purebreds will be used in the practice, and there should be a demand for many purebred boars."

The pedigree of the pigs following several generations of crisscross-breeding would be as shown in the following illustration.

Hamp. 31¼%
D. J. 68¾%

Duroc Jersey Boar

Sow
Hamp. 62½%
D. J. 37½%

Hampshire Boar

Sow
Hamp. 25%
D. J. 75%

Duroc Jersey Boar

Sow
Hamp. 50%
D. J. 50%

Hampshire Boar

Duroc Jersey Sow

The three-breed-cross system of mating can be shown as follows:

	Duroc Jersey Boar			
D. J. 56¼% Hamp. 31¼% C.W. 12½%		Hampshire Boar		
	Sow Hamp. 62½% C. W. 25% D. J. 12½%		Chester White Boar	
		Sow C. W. 50% Hamp. 25% D. J. 25%		Hampshire Boar
			Sow Hamp. 50% D. J. 50%	
				Duroc Jersey Sow

Discussion. Despite the fact that there are many outstanding pork producers who follow a crossbreeding program with success, there are a number of facts which argue strongly against its general adoption. The farmer who is ambitious to improve his grade herd, and most herds are grade in breeding and most are in need of improvement, many believe would be better advised to stick with the breed which he prefers, which is adapted to his conditions, and with which he is most familiar, rather than experimenting with crossbreeding. He will more likely be able to secure satisfactory sires from his own breed than from some other with which he is not so well acquainted. He is often apparently deluded by the thought that there is some magic in crossing, and he chooses a boar more or less at random, with too much thought to breed and too little to individual merit.

The first cross looks good and performs satisfactorily in the feed lot, but from there on certain complications and difficulties arise. If first-cross pigs are to be produced each year it will necessitate the maintenance of two different classes of hogs, one for the production of the cross-bred pigs, the other to provide replacements for the sow herd. As a consequence of this, the plan frequently degenerates into a mixed and indiscriminate type of mating characteristic of the shiftless type of farmer who operates on the "catch-as-catch-can" plan. In the crisscross or three-breed-cross systems, however, this difficulty is not present, although the final results may be the same if the program is not faithfully adhered to.

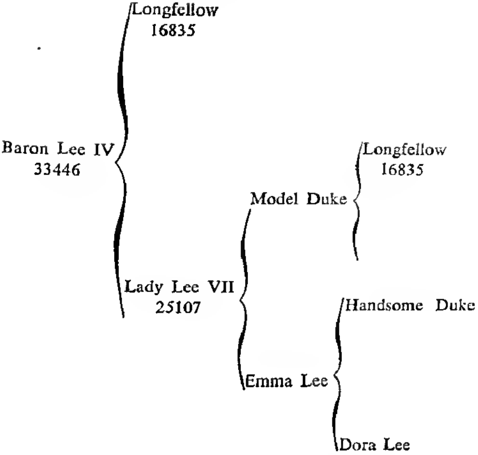
It is the considered opinion of the author that commercial pork producers in general will gain more by staying with one breed and persistently following a constructive program of upgrading than they will by embarking on any one of the plans of crossbreeding. It is pertinent to observe here, however, that either system may be followed by a good hogman with expectation of good results, and that the difference in favor of one or the other under like conditions is not great nor nearly so important as those which result from the usual differences found in management and feeding practices.

Inbreeding: line-breeding. In principle, inbreeding is the opposite of crossbreeding. It means the mating of individuals more or less closely related. If the individuals are as closely related as full brother and sister, half brother and sister, sire and daughter, or dam and son, it is called close inbreeding or incestuous breeding. Practically all inbreeding takes the form of line-breeding. Line-bred pedigrees show the repeated appearance of some one animal. The result is that it intensifies the influence of this individual, or of the group of individuals *just back of him* in the pedigree.

D. B.'s Dutchess 76842	High Chief 13423	Ohio Chief 8727	
		Arlie M. 28520	
	Watson's Dutchess	John's Ohio Chief 17483	Ohio Chief 8727
		Maywood S. 4th 3240	

A good example of line-breeding frequently seen is represented in the pedigree of D. B.'s Dutchess 76842, as shown in the above diagram. In this case a son of Ohio Chief was mated with a granddaughter of Ohio Chief.

In the illustration below is the pedigree of Baron Lee IV 33446 which shows a little closer line-breeding than the first.



The relationship is even more close than shown here for Handsome Duke was a half-brother to Longfellow, and Dora Lee was a full sister.

Is inbreeding safe or practical? The commercial breeder of market hogs may well eschew inbreeding. The availability of good boars of the breed outside his herd is such that he cannot afford the risks of impaired fertility and vigor which generally follow the use of too closely related sires. Breeders of purebred stock, however, have in a large number of instances employed it for a time with eminently satisfactory results.

Robert Bakewell of Leicestershire, England, the father of animal breeding, who began breeding livestock in 1760, mated "the best to the best," it is said, regardless of relationship. He succeeded in effecting such improvement in the meat and early maturing qualities of his Longhorn cattle and Leicestershire sheep that his method was hailed as a new and sensational discovery. Cruickshank was another early constructive breeder whose fame largely rests on the get of Champion of England. From the time this great bull was produced, only sires of his own breeding were used. The founders of the Angus and Hereford breeds likewise did not hesitate to inbreed "when the animals were strong and suited to one another." Practically all of the early breeders

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In the illustration below is the pedigree of Baron Lee IV 33446 which shows a little closer line-breeding than the first.

Poland China, Tamworth, and Chester White breeds were selected and a program of continuous brother-and-sister mating of littermates initiated.

At the end of 5 years the results obtained were summarized with the following significant observations. The pigs showed a marked decline in vigor and later in fertility, more in some lines than in others. There was an increased susceptibility to disease. One line of Poland Chinas became extinct after the first generation; the second line carried on into the second generation, but farrowed an average only of two pigs to the litter, and efforts to continue it were abandoned. A similar fate overtook one of the Chester White lines. Two Tamworth gilts lost their litters before farrowing time, and repeated the performance the next year. After five years only on line, a Tamworth, had produced a fourth-generation litter. Two latent characters, a sepia color in one of the Poland lines and swirls in a Tamworth line, were brought to light and fixed. In addition, there often appear in intensively inbred lines such lethal or defective characters as cleft palate, scrotal hernia, defective skulls, ridgelings, absence of a normal anal opening, etc.

These results conform to expectation and are in accord with known genetic laws. They are of practical value to the breeder in informing him of the dangers which are inherent in any such intense inbreeding program.

A national breeding research laboratory is created. That inbreeding has been used successfully, and is now being employed in a mild form by a number of breeders with good results, suggest that it has possibilities that have not yet been fully realized. It was chiefly to explore these possibilities that the *Regional Research Laboratory for the Improvement of Swine through Breeding* was created by the Bankhead-Jones Act of 1935. According to the Twelfth Annual Report of the director of the Laboratory, Dr. W. A. Craft, there now are 17 state experiment stations collaborating with breeding projects directly or informally related to the cooperative effort.

The broad-scale objectives of the Laboratory, as stated, are "to discover, develop, and test procedures of breeding and selection which may be used by hog producers to speed the improvement of hogs in respect to performance and carcass; to study precisely the usefulness of inbred lines for improving the breeding value of the pure breeds for use in pork production; to enlarge knowledge concerning the genetic effects of inbreeding and inheritance of characters in swine, and to evaluate application of such knowledge in swine breeding."

of livestock whose detailed records are known practiced inbreeding to a greater or lesser degree. Gentry of Berkshire fame is a more recent breeder whose success was in large measure the result of the careful mating of individuals descended from the great boar Longfellow 16835. The late great Hereford breeder, Robert H. Hazlett, maintained a closed herd for a period of about 30 years.

It would be a mistake, however, not to emphasize the fact that practically every one of these breeders recognized in their experience the dangers which lie hidden in the system. Practically all of those who used inbreeding to fix type and establish uniformity came to the point where they saw the necessity of introducing fresh blood by making an outcross. This was apparent in an increasing tendency towards sterility and a lack of vigor as the line was continued.

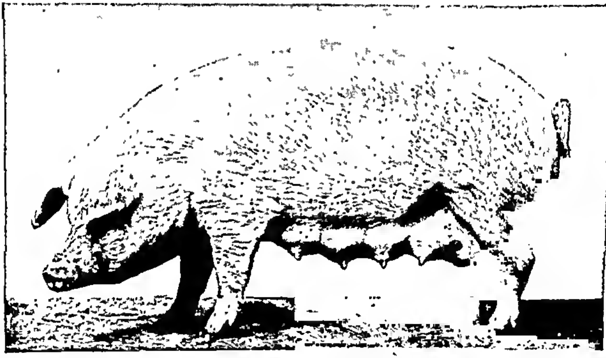

Fig. 107. This line-bred Chester White sow, Purdue's Miss Model, was a littermate to the International grand champion barrow of 1933 and the mother of the International grand champions of 1934 and 1935, each by a different sire *(courtesy, Purdue University)*.

Hazards involved in continuous inbreeding. What usually happens in swine when an intense inbreeding program is followed for several generations is well illustrated by the results of an experiment carried out by the Division of Animal Husbandry of the U.S. Department of Agriculture from 1924 to 1929.[3] Two pairs of pigs from each of the

[3] Hugh C. McPhee, *The Extension Animal Husbandman*, U.S.D.A., March, 1929.

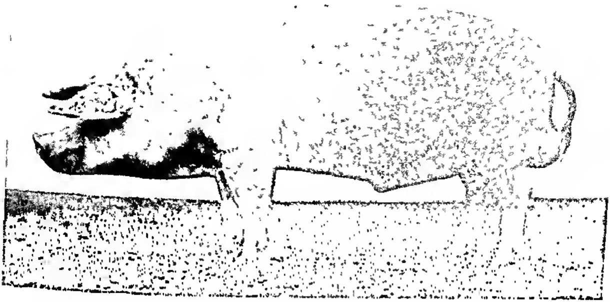

Fig. 108. Danish Landrace boar, 4 years old. A good representative of this famous bacon breed *(courtesy, Bureau of Animal Industry, U.S D.A.).*

selection those which are undesirable. It is a means, therefore, of securing prepotency, fixing type, and establishing uniformity in a herd. The rather extensive practice of inbreeding in the early formation period of many of our present breeds of livestock was justified by these facts.

2. When inbreeding is continued for several generations it almost inevitably results in loss of vigor and fertility, even though the weak and infertile are automatically eliminated in each generation both by natural and artificial selection. The more intense the inbreeding practiced, the more certain is it that these results will follow. Even when as mild a form as inbreeding of first cousins or uncle and niece is practiced these results are likely if the program is continued.

3. The hazards inherent in an inbreeding program are such that most breeders cannot afford to contend with them. The number of satisfactory boars now available within any of our major breeds is such as to make unnecessary the use of those too closely related to the herd. Occasional mild inbreeding or line-breeding is justified, however, when through good fortune an outstanding sire has been found and maximum use of his superior qualities is sought

4. The production of inbred lines within breeds, or from a cross of two or more breeds, in the hope of finding and establishing near pure strains superior to anything yet produced, is a long and costly process which the breeder may well leave in the hands of the experi-

Points emphasized in selection are productiveness in sows, vitality, rate and economy of gains, and carcass quality of the pigs.

Attainment of these objectives is systematically being sought by the principal cooperating stations by rigid selection for desirable new combinations of characters (genes) brought about through inbreeding and crossbreeding. At six of the stations the projects underway involve moderate inbreeding within a single breed, five major breeds being used; at one station moderate inbreeding is being pursued in a herd based on a cross of two breeds; and one station is practicing intense inbreeding of strains within one breed and of strains developed from a cross of two breeds.

Inbreeding in most instances here is being employed as a means of developing superior near homozygous or pure strains which, when crossed on other similar surviving lines, will result in the restoration of lost vigor as well as providing genetic material for new and possibly superior combinations of characters.

There are undoubtedly present in our hog population genetic elements (genes) of sufficient variety and kind, some of which if successfully isolated and combined would produce a superior variety of hog. The number of lines which it would be necessary to develop and test before finding one or two which possess the qualities sought, however, is very great, if we are to judge from the experiences of the corn breeder; possibly as many as a thousand or more would be necessary.

Progress towards the attainment of any of these objectives is necessarily slow also because of other difficulties which normally arise in any inbreeding program. Because of the limited number of animals in the foundation herds and the usual decline in vigor and fertility which follows from close breeding, the number of offspring available in any generation from which selections can be made is seriously limited.

Theoretically, it would appear that the system most likely to locate desirable characters (genes) in the shortest time would be one which permitted the use of unlimited foundation material and from which innumerable lines could be developed through a program of intensive inbreeding.

Summary of observations on inbreeding effects.

1. In terms of the practical breeder, inbreeding has the effect of simplifying and purifying the hereditary or breeding qualities of the individual. This it does by bringing into expression characters which were once latent or hidden, thus enabling the breeder to eliminate by

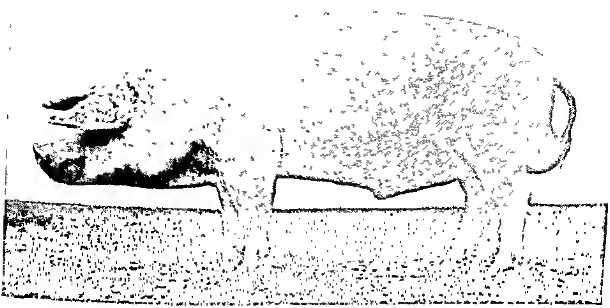

Fig. 108. Danish Landrace boar, 4 years old. A good representative of this famous bacon breed *(courtesy, Bureau of Animal Industry, U.S.D.A.).*

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ment stations with their trained geneticists. There probably is present in every breed a sufficient variety of valuable unfixed characters which, if successfully combined, would be capable of effecting improvement in our pork-producing seed stock. This is the program to which the Regional Research Laboratory for the Improvement of Swine through Breeding is dedicated. Although the practical accomplishments of the program, thus far, have been somewhat disappointing much has been learned concerning the heredity of individual characters.

IDEALS IN BREED AND HERD IMPROVEMENT

One of the outstanding characteristics of the methods employed by the great breeders of the past, to whom the livestock industry owes so much, was that each one had in mind a definite objective or goal for which he persistently selected through many generations. A second characteristic, in the case of those who achieved the most in lasting values, was that this goal was a practical one; that is, was concerned mainly with those characters which are essential to practical herd performance.

Prolific sows. Probably the most important factor in efficient herd performance is productiveness on the part of the sows. It is essential in economical pork production, and is the trait upon which mainly hinges a breed's popularity with the farmer.

The natural ability of sows to breed regularly and produce and raise large litters is an inherited trait, and can be developed and maintained in the herd only by selecting for this kind, and by rigorous culling of those which fail to perform satisfactorily. Such a policy is the first essential in the successful management of a herd of hogs, whether purebred or grade.

In addition to keeping in the herd only those sows with good performance records, the gilts retained for breeding should be selected only from the most productive mothers and prolific families. The sows that raise the large litters are heavy milkers and usually are thin and not too good to look at when their pigs are weaned; but this is the kind from which replacements for the breeding herd should be selected.

In maintaining a high level of breeding performance in the herd, the selection of the untried boar should be made with the same discriminating attention as is given in the selection of the gilts. The size of the litter is limited by the number of eggs produced by the sow;

the boar to which she is bred, if vigorous, is believed to have no influence, except in special cases (see page 116). However, the sow's ability to farrow a large number of pigs is influenced as much by her sire as by her dam. Therefore, if he is not from a good litter and prolific strain he may do more harm to the herd than good, even though he may have been a junior champion in the showring.

Feed-lot performance. The second important consideration in profitable pork production is feeding quality. By this is meant the ability on the part of the pigs under good feeding conditions to reach a market weight of 225 pounds by the time they are 5 to 6 months of age. Along with this capacity for rapid and economical gains, the farmer also requires pigs which will have the desired finish or condition when market weights are reached. In a group of pigs of the same breeding, those that gain fastest usually fatten quickest and are in better condition at market weights.

To secure and maintain in the herd capacity for rapid and economical gains during the early growth period of the pig means that size for age, considering treatment, must be given adequate consideration when the boar and gilts are selected. What is wanted are early growth gains rather than extreme mature weights. As a rule, however, the larger the parents at maturity, provided they are not of the extreme rangy type, the greater will be the gaining capacity of their pigs.

To meet the requirements of the feeder and market, consideration must be given to the nature or character of the gains, as well as to their amount. Along with gaining capacity there must be the disposition to fatten at a sufficiently early age to ensure the desired finish at market weights. At the same time there must not be too much of this disposition to fatten early, for such hogs carry more fat and lard than the market can absorb profitably. This means that the matter of type, as expressed in the general conformation, must always be considered, with some attention also to smoothness and quality. Experiments and practical experience have shown rather conclusively that the so-called intermediate type produces pigs which make more rapid early gains, and which at the same time have more nearly the desired finish at the popular market weights than do either the tall rangy type, on the one hand, or the short chuffy type on the other (see page 153).

As a rule, those pigs in the same herd which make the most rapid gains under a given feeding system also make the most economical gains. Some studies indicate a degree of correlation between them as high as 80 percent. The most economical gains, however, are made

ment stations with their trained geneticists. There probably is present in every breed a sufficient variety of valuable unfixed characters which, if successfully combined, would be capable of effecting improvement in our pork-producing seed stock. This is the program to which the Regional Research Laboratory for the Improvement of Swine through Breeding is dedicated. Although the practical accomplishments of the program, thus far, have been somewhat disappointing much has been learned concerning the heredity of individual characters.

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One of the outstanding characteristics of the methods employed by the great breeders of the past, to whom the livestock industry owes so much, was that each one had in mind a definite objective or goal for which he persistently selected through many generations. A second characteristic, in the case of those who achieved the most in lasting values, was that this goal was a practical one; that is, was concerned mainly with those characters which are essential to practical herd performance.

Prolific sows. Probably the most important factor in efficient herd performance is productiveness on the part of the sows. It is essential in economical pork production, and is the trait upon which mainly hinges a breed's popularity with the farmer.

The natural ability of sows to breed regularly and produce and raise large litters is an inherited trait, and can be developed and maintained in the herd only by selecting for this kind, and by rigorous culling of those which fail to perform satisfactorily. Such a policy is the first essential in the successful management of a herd of hogs, whether purebred or grade.

In addition to keeping in the herd only those sows with good performance records, the gilts retained for breeding should be selected only from the most productive mothers and prolific families. The sows that raise the large litters are heavy milkers and usually are thin and not too good to look at when their pigs are weaned; but this is the kind from which replacements for the breeding herd should be selected.

In maintaining a high level of breeding performance in the herd, the selection of the untried boar should be made with the same discriminating attention as is given in the selection of the gilts. The size of the litter is limited by the number of eggs produced by the sow;

the boar to which she is bred, if vigorous, is believed to have no influence, except in special cases (see page 116). However, the sow's ability to farrow a large number of pigs is influenced as much by her sire as by her dam. Therefore, if he is not from a good litter and prolific strain he may do more harm to the herd than good, even though he may have been a junior champion in the showring.

Feed-lot performance. The second important consideration in profitable pork production is feeding quality. By this is meant the ability on the part of the pigs under good feeding conditions to reach a market weight of 225 pounds by the time they are 5 to 6 months of age. Along with this capacity for rapid and economical gains, the farmer also requires pigs which will have the desired finish or condition when market weights are reached. In a group of pigs of the same breeding, those that gain fastest usually fatten quickest and are in better condition at market weights.

To secure and maintain in the herd capacity for rapid and economical gains during the early growth period of the pig means that size for age, considering treatment, must be given adequate consideration when the boar and gilts are selected. What is wanted are early growth gains rather than extreme mature weights. As a rule, however, the larger the parents at maturity, provided they are not of the extreme rangy type, the greater will be the gaining capacity of their pigs.

To meet the requirements of the feeder and market, consideration must be given to the nature or character of the gains, as well as to their amount. Along with gaining capacity there must be the disposition to fatten at a sufficiently early age to ensure the desired finish at market weights. At the same time there must not be too much of this disposition to fatten early, for such hogs carry more fat and lard than the market can absorb profitably. This means that the matter of type, as expressed in the general conformation, must always be considered, with some attention also to smoothness and quality. Experiments and practical experience have shown rather conclusively that the so-called intermediate type produces pigs which make more rapid early gains and which at the same time have more nearly the desired finish at the popular market weights than do either the tall rangy type, on the one hand, or the short chuffy type on the other (see page 153).

As a rule, those pigs in the same herd which make the most rapid gains under a given feeding system also make the most economical gains. Some studies indicate a degree of correlation between the two as high as 80 percent. The most economical gains, however, [illegible]

by the pigs when on a two-thirds to three-fourths full ration than when on a full ration (see page 158).

Market suitability. The third objective which the successful breeder keeps in mind is to produce the kind of finished product which will satisfy the demands of the packer and consumer. This is a market hog which will weigh 180 to 240 pounds, which yields well and which, when carrying the right condition, neither too much nor too little, furnishes the weight and quality of cuts that are in widest demand.

To produce this kind, breeding stock of the intermediate type must be selected. This type not only is consistent with reproductive ability and good feed-lot performance, but also produces carcasses which are highly acceptable to the packer. Farmers sometimes find it more profitable, however, to sacrifice a little on selling price in order to market at heavier weights. This is likely to be the case in years when corn is cheap and hogs are relatively high in price. In order to avoid excessive condition when hogs are marketed at the heavier weights, the boar used should have a little more "stretch" than when anticipating a marketing weight of around 200 pounds, but he still should be of the intermediate type.

If breeders of pedigreed hogs are to produce the kind of boars needed to improve farm herds, they too must bear in mind the requirements of the market. That they are at the present time increasingly aware of this need is shown by the record. As a result of the well-directed activities of the breed associations, national in scope, in promoting production-record testing, type conferences, barrow shows, and carcass contests, breeders are now better informed on packer and consumer, as well as farmer, requirements than they have been at any time in the past. The present breeder's type, as exemplified in the present show-ring standards, is one which more consistently meets the practical requirements of the farmer and market than any in the past (see page 514).

GUIDES IN SELECTING BREEDING STOCK

How best to attain these objectives or goals, as breeders, is the difficult problem. Its solution will be determined largely by the judgment exercised in the selection of breeding stock. There are three ways of judging an animal's worth as a breeder: first, by his individuality; second, by his pedigree or ancestry; and third, by the test of actual performance in the herd.

Individuality is related to breeding performance. By individuality is meant everything about the animal which can be seen or judged, such as size, conformation, quality, and breed-type features. Show-ring judging is based entirely on a consideration of the visible characters making up the individual. It has been in the past, and probably will continue to be in the future, the one best guide in judging the prospective breeding value of the untried sire or dam.

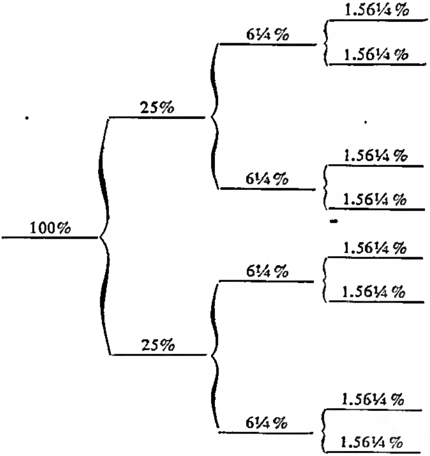
Consideration of the individuality is of supreme importance because it is an expression, although not a complete one, of the hereditary character of the germ plasm. In ordinary breeding practice, we can judge the nature of the germ plasm of the untried sire, for example, only by what is expressed in the individual and the individuals of his immediate ancestors. It is largely because of this relationship that poor judges of individual merit never become successful breeders.

But the individuality of an animal is not only a product of his inheritance, but also of the opportunities which he has had for development. He may be well bred, but poorly fed; or he may be well fed and poorly bred. In the first instance he would likely be valued below his actual worth, and in the latter, above his value. The individuality reflects most accurately prospective breeding value only when good feeding and management have combined to ensure full development of the individual's hereditary possibilities. Overfitting for the show or sale ring, however, should be deplored. Not only is it a waste of feed, but it makes more difficult an accurate appraisal of the individual's worth.

The pedigree is an aid in selection. A pedigree is a statement of an animal's ancestry. In addition to the names and herd-book numbers of the animals in each of several generations, usually it includes also the date of birth of each animal and the name of the breeder. It may extend back to the beginning of a breed's recorded history, or only for two or three generations.

prepotent and uniform the breeding qualities of the individual may be expected to be.

The most important animals in a pedigree, from the standpoint of their resemblance to, or influence in determining, the character of the individual under consideration are those which appear in the immediate ancestry. According to the old Galton law, which was based mainly on a statistical study of human stature, the two immediate parents have twice the influence of the four grandparents; and the eight great-grandparents together exert only half the influence of the four grandparents, etc. The influence of any single individual, therefore, is four times that of any individual in the preceding generation. This relationship or distribution of influences may be illustrated as follows:



The importance which the prospective buyer should attach to the pedigree of a young boar or gilt is conditioned by his knowledge of the individuality and breeding record of the individuals in the immediate ancestry. If this information is complete and gained largely from first-hand observation, he should base his judgment of value about one-half on the merit of the individual and about one-half on

the pedigree. Since in practice this knowledge always is incomplete at the best, the individuality of the animal should have the primary consideration.

Performance is the final test of value. The real value of an animal for breeding purposes can be determined only by a performance breeding test. For this reason a tested boar is more reliable than a pig, and judgment of his prospective value is likely to be more accurate. It should be remembered, however, that the successful performance of a sire in one herd does not guarantee for him an equal value in another herd. This suggests that both the individuality and pedigree of the boar should be considered always in relation to the type and breeding of the sows with which he is to be mated.

The brood sow that has demonstrated her ability in raising pigs of the right kind and numbers should retain her place in the breeding herd so long as there are no better ones, according to the same standard, to take her place. Especially in the purebred herd, the sows represent the survival result of all the past generations of careful selection, and, by virtue of this fact, have acquired an importance which too often is not appreciated. The tried sow should not be discarded lightly, even though in appearance she compares unfavorably with the gilts.

XXII Sanitation and Disease Control

By Dr. L. M. HUTCHINGS

SANITATION MEASURES FOR THE PREVENTION OF DISEASE

Sanitation as related to management. Sanitation is an important part of herd management. It may be defined as the application of the necessary health-conserving and disease-prevention measures to the care, management, and feeding of hogs. Close confinement and crowded quarters tend to increase the likelihood of disease. Filthy feeding floors and watering places favor the entrance of disease-producing germs into the body of the animal. Hogs do not thrive well when the housing conditions encourage them to pile up in the sleeping quarters or burrow into straw stacks. Wet, filthy, or dusty beds are detrimental to raising thrifty swine. Straw stacks, old straw sheds, and hog houses that have dirt floors are unsatisfactory shelters for hogs.

Manure, corncobs, and other litter should not be allowed to accumulate in the hog houses and yards. In case the yards do not have good surface drainage, grading and tiling them helps to correct this condition. Small lots may be cleaned by removing a few inches of the surface. The most effective way to clean a hog lot is first to remove all litter and then to plow it and to sow rye, wheat, rape, or other forage crops.

The two most important sanitary requirements in a central hog house are good ventilation and clean, dry floors. Ventilation without floor drafts is important during cold weather. Unless the floor can be easily cleaned, the house usually becomes filthy. A concrete floor provided with drains can be washed with water and is easy to keep clean. Stiffness and lameness often occur in hogs confined too long inside a central hog house. This condition may be corrected by allowing them outside for exercise. Open sheds and portable hog houses, under most farm conditions, are more satisfactory than a central house for hogs and young pigs.

If hand-feeding is practiced, a concrete feeding floor large enough to accommodate the entire herd should be provided. The floor should

be kept clean; otherwise it is little better than feeding on the ground or in the mud. If garbage is fed, the feeding floor should be thoroughly cleaned daily. It is better to select a different feeding place from day to day when hogs are fed ear corn in the pasture. Shelled corn, ground feed, tankage and minerals are usually fed in self-feeders.

Water from a good well in clean troughs or in a drinking fountain assures a safe water supply. Small streams usually receive drainage from other hog lots and are common sources of disease. Ponds and wallows are little better than cesspools, as they receive surface drainage from the hog lots and pasture. They should be filled in with dirt in order to prevent hogs from using them for drinking and wallowing places.

Disinfecting hog houses. The first step in disinfecting a hog house is to thoroughly clean the walls and floor. Ninety percent of the time and labor should be spent in cleaning and only 10 percent in disinfecting. It is impossible to disinfect a dirty hog house. The surface of an earth floor should be removed to a depth of 2 or 3 inches and replaced with clay or gravel. One pound of lye in 10 to 20 gallons of hot water is commonly used by the farmers and breeders in cleaning hog houses. A 3 percent water solution of liquor cresolis compound (sheep dip) may be sprayed or sprinkled on the cleaned surfaces. Sufficient hydrated lime may be added to the disinfectant to make a thin whitewash. This enables the person who is applying the disinfectant to detect any part of the surface that has been missed. The pump used should have sufficient force to drive the spray into the cracks and uneven places in the walls and floors.

Proper diagnosis of swine diseases. The high death rate from infectious diseases of hogs cannot be lowered without the cooperation of all farmers, breeders, and dealers. The buying and selling of diseased hogs and hogs that have been exposed to infectious diseases costs annually hundreds of thousands of dollars. Infectious diseases can be controlled in a community by quarantining the sick and exposed hogs. An early diagnosis is all-important. A delayed diagnosis allows the infection to spread in the herd and community.

Salesmen should not be allowed to diagnose and treat diseases of hogs. Very few salesmen are veterinarians, and the desire to make a sale may influence the diagnosis. If both the diagnosis and instructions for caring for the herd are wrong, it makes little difference whether fraudulent or honest drug preparations and vaccines are used for the treatment of the disease, as the final results would be the same.

The diagnosis and treatment of hog diseases by agents for drug preparations, vaccines, and so-called remedies and cures have interfered with the control of infectious diseases and increased the cost of hog production.

INTERNAL PARASITES OF SWINE

Although there are numerous parasites which may affect swine the most common are the common roundworm *(Ascaris suum)* and the thorny-headed worm *(Macracanthorhynchus hirudinaeceus).* Two others, less common but deserving of mention, are the kidney worm *(Stephanurus dentatus)* and Trichinella spiralis.

The common roundworm. Very few hogs escape infestation with common roundworms. Injury by this parasite is limited largely to pigs. The eggs of the roundworm pass out of the hogs' intestine in the feces. Eggs develop to the infective stage outside the pig's body and are then taken into the digestive tract in feed and water contaminated with filth, and reach the immature stage in the intestine. The young worms penetrate the intestinal wall and enter the small blood vessels. They are carried in the blood stream to the liver, lungs, and spleen (melt). Larvae that escape from the lung capillaries into the small air sacs migrate to the pharynx (throat) and pass down the esophagus (gullet) to the intestine where they complete their development. During this migratory period the young worms may damage the liver and lungs. In fact, the chief injury from the common roundworm occurs during *the migration period rather than from the adult worms in the intestines.*

The thorny-headed worm. The thorny-headed worm is not a common parasite of swine grown in the Corn Belt states, but it is of considerable economic importance in the southern part of the United States. Certain beetles and their larvae are the intermediate hosts of the thorny-headed worm. The adult worm inhabits the small intestine of swine, to which it is attached. The eggs pass out of the intestine with the excrement and hatch when ingested by the larvae of certain beetles, which feed in the manure or the soil of infected pastures and hog lots. Treatment has not proved satisfactory. Prevention consists of keeping swine from eating white grubs and beetles that are infested with the young worm.

Clean hog lots prevent mass infection in pigs and consequent injury to the lungs, liver, and kidneys. Young pigs should not be kept in central hog lots. Use of the McLean County System of swine sanitation helps limit mass infection of pigs with roundworms. "Worm remedies"

are often not effective in controlling this parasite. Often the death of a pig is wrongly attributed to "worms" when the autopsy reveals round worms in the intestine. A "worm remedy" is then often given to the entire herd. The mere finding of adult roundworms is not positive evidence that this parasite has caused the pig's death. If the disease or cause of death should be cholera, flu, dysentery, or anemia, the treatment of the herd with a "worm remedy" may actually increase the death rate. Furthermore the use of "worm remedies" by inexperienced persons may result in injury to the pharynx, stomach and intestine which results in stunting or death of the pigs. The general, promiscuous use of drugs should not be employed for the treatment of intestinal worms in swine.

Kidney worms. The kidney worm *(Stephanurus dentatus)* is widely distributed in tropical and semitropical areas. Thus they are of importance to swine raisers in the Deep South of the United States, but are not of much importance in the Corn Belt. They occur mostly in the fat surrounding the kidney itself, and in the uterus or pig-bed. The adult worms live in cysts which communicate with the tubes that carry the urine from the kidneys to the urinary bladder and hence the eggs pass out in the urine of the pig. The eggs hatch and the larvae reach the infective stage in about 4 days under favorable conditions. Infection of the host occurs by mouth or through the skin. The young worms which enter swine by either route migrate to the liver and eventually establish themselves in the area surrounding the kidney. Treatment has been unsatisfactory. This parasite is mentioned because, although there is a difference of opinion concerning its importance, some authors consider it as a cause of posterior paralysis. The chief importance of the parasite is that the kidneys, liver, and occasionally other organs may be unfit for human consumption. Other diseases are usually found to be the cause of posterior paralysis.

cooking of all pork and other meat that are fed to pigs and, of course, thorough cooking of all meat for human consumption.

EXTERNAL PARASITES OF SWINE

The two most common parasites of the skin of swine are the hog louse *(Haematopinus suis)* and the mange mite *(Sarcoptes scabiei suis)*. Both of these parasites are widely distributed and are very prevalent in the Corn Belt.

The hog louse. The hog louse is the largest of those found on farm animals. Because of its size and the thin hair of swine it can be easily seen with the unaided eye. The eggs (nits) also may be seen attached to the hairs. The eggs hatch in 10 or 12 days and the young louse reaches maturity in 2 or 3 weeks. This louse sucks blood and a heavy infestation may cause swine to become restless and unthrifty. Hog lice frequently get onto humans, but do not stay long and do little or no damage. Swine pox may be spread by lice.

Lice may be controlled effectively by the use of crude petroleum or processed crude petroleum. The petroleum may be applied in a dipping tank, by hand, or by means of hog oilers designed for the purpose. A newer and effective treatment consists of spraying the hogs with benzene hexachloride or chlorodane (directions on the container). One application is ordinarily sufficient to remove all lice.

Mange. The mange mite burrows into the skin and lays eggs in the tunnel so formed. The entire life cycle requires 2 to 3 weeks. These mites cause intense itching, which results in rubbing or scratching, which aggravates the condition. The skin becomes crusted, thickened, cracked, and often grayish in color. Swine lose the hair in the affected areas. The thickened skin is referred to as "elephant hide." Mange usually starts around the eyes, nose, or ears, but it may appear first on any part of the body. Mange may occur at any time of year, but is seen chiefly in the winter when swine are closely confined. Because swine seldom, if ever, die of mange, the serious economic loss from the disease is overlooked by many owners. Hogs affected with mange not only are unthrifty and inefficient but also may be docked at market because of the severe skin damage which may result in condemnation of hams and shoulders.

Treatment consists of repeated applications of lime-sulphur dip, crude petroleum or processed crude petroleum. A newer and very successful treatment consists of a single application of benzene hexa-

chloride or chlorodane with a sprayer. Thus one may treat for both lice and mange with a single spraying.

DISEASES OF YOUNG PIGS

Anemia. Anemia is a serious nutritional disease which occurs in young pigs that are kept too long from contact with the ground. Young pigs which grow rapidly on milk alone may become severely anemic by the time they are 2 to 3 weeks of age. Thumps and scours are common symptoms of anemia. Other symptoms are lack of vigor, paleness, and, in the advanced stage, wrinkling of the skin and edematous swelling along the under side of the body, particularly the neck. When exercised, anemic pigs show labored breathing and they become greatly fatigued. Most of the losses from anemia occur during the winter and early spring in pigs confined to the central farrowing house, or in pigs which do not go outside because of unfavorable weather.

Pigs that recover are often unthrifty and stunted, and their resistance to parasitic and other diseases is lowered. Enteritis, bullnose, pneumonia, and heavy infestation with lung and intestinal worms are likely to occur in herds where there have been severe cases of anemia.

On post-mortem examination anemia is easily recognized by the pale blood, pale muscles, yellow liver, enlarged spleen, and flabby and frequently dilated heart. In case several pigs in a herd show symptoms of anemia, one or more should be autopsied by a veterinarian, and if the trouble proves to be anemia, the conditions responsible for the disease should be corrected.

Baby-pig disease. A satisfactory crop of baby pigs is essential for successful swine production. Anything which interferes with a satisfactory pig crop is of great concern to the swine producer and his veterinarian. Determining the causes of death losses in new-born pigs is quite often a most difficult problem. There is now quite general agreement among investigators that feeding an inadequate ration to the brood sows during the gestation period is responsible for some of the high death losses in baby pigs. This type of death loss occurs in pigs that are born at full term, and of sows that are apparently healthy. Ordinarily these pigs appear normal at birth and usually nurse within a sbort time. In a few days, however, they weaken and die.

Tbe symptoms associated with these pig losses are sometimes not clearly defined. Death may occur at any time from several hours to several days after birth. The symptom commonly observed is apathy. The pigs remain in the nest almost constantly. In some instances they wander aimlessly about the pen, shiver, go into a coma and may be found lying scattered on the floor of the farrowing pen or house. Lack of vigor and coma are probably responsible for many deaths that are attributed to the pigs being "laid on" by the sow. An active, vigorous pig will usually avoid being laid on by the sow. When affected pigs are handled, they often emit an abnormal squeal. Farmers often refer to this as a "graveyard squeal" because their experience has shown that death of the pig is likely to occur soon.

Post-mortem examination shows certain lesions to be fairly constant. The liver is increased in size and is more friable than normal. There is a tendency for the liver to rupture, as the result, perhaps, of a slight pull on the unbilical cord or pressure on the body. A doughy swelling that pits on pressure, particularly along the underportion of the neck and between the hind legs, is often seen. In addition, degeneration of the kidneys is apparent. The stomachs of the dead pigs are often well filled with milk.

Careful observations and some experimental work have indicated that this condition results from faulty nutrition of the sow or gilt during the gestation period. The precise kinds and amounts of the various nutritional factor which should go into the brood-sow ration have not been fully determined. However, there is information available indicating, in a general way, what a successful ration should contain. The addition of good-quality alfalfa meal, 15 to 25 percent of the ration, when the sows are not on pasture is now generally recommended in order to improve the liveability of the pigs. However, the addition of

alfalfa meal to a decidedly poor ration cannot be expected to supply all of the nutritional factors required by the pregnant sow. Good-quality pasture is of extreme importance. For full details concerning adequate brood-sow rations see Chapter III.

SWINE BRUCELLOSIS

There are some contagious diseases which may cause an unsatisfactory pig crop. Two of these are brucellosis and transmissible gastroenteritis. Brucellosis of swine is a chronic infectious disease caused by a specific germ (*Brucella suis*). The symptoms are varied. The more common symptoms are abortion, the birth of dead or weak pigs, temporary or permanent sterility, and, less commonly, joint swellings and posterior paralysis. The disease affects both males and females of all ages. The symptoms are more pronounced in adult animals than in young pigs.

Brucellosis of swine is one of the important problems of the swine industry. It is estimated that between 1 and 3 percent of the hogs are affected with this disease. Although exact figures on incidence are not available, the disease is known to be of considerable economic importance to the swine producer. The losses occur through (1) abortions; (2) the birth of dead pigs at farrowing time; (3) the birth of weak pigs, some of which die; (4) failure of gilts and sows to become pregnant; and (5) sterility in the boar when the germs localize in the genital organs.

transmitted by indirect means such as contaminated feed, trucks, shows, creeks, and contaminated premises. Infected sows and gilts eliminate the germs in the discharges at the time of parturition (either full term or premature). The bacteria may be found in milk of infected females and semen of boars, and has been demonstrated in urine and manure. Pigs may become affected while nursing infected dams and act as spreaders. Primarily, brucellosis is spread by traffic in breeding hogs from diseased herds to clean herds, and is then perpetuated in the herd largely by breeding animals.

Infectious abortion or swine brucellosis is rather difficult to eliminate from a herd. However, the disease, in so far as abortions are concerned, is much more self-limiting than brucellosis in cattle. There is no accepted vaccination procedure or treatment for this disease; hence, control is based on diagnosis and elimination or isolation of infected animals.

Diagnosis is accomplished by the standard blood-agglutination test, similar to the test for brucellosis in cattle. In swine this test is accurate in detecting brucellosis in a herd, but has some limitations in diagnosing the disease in individual swine. These limitations are due to (1) the absence of a blood reaction in the early stages of the disease, even though the animal is harboring the germs, (2) the presence of a slight blood reaction in both infected and noninfected swine, and (3) the disappearance of blood reactions in some infected swine.

Prevention measures. The most important preventive measure is to avoid introducing infected swine into a brucellosis-free herd. This is best accomplished by purchasing replacements or additions from herds known to be free of brucellosis. In the event such is not possible, each addition should be tested. No animal showing an agglutination reaction in any degree should be accepted. Replacements from herds of unknown disease history should be kept in isolation for at least three months and retested before entry into clean herds is permitted.

Assembling a swine herd from many different sources is dangerous. It is safer to limit the purchase of animals to one source, if possible, and thus lessen the chance of purchasing an infected hog which is not reacting to the blood test. Herd sires should be purchased well in advance of breeding season so that at least two blood tests, at 30- to 60-day intervals, can be made prior to their use. Such quarantine periods may appear to be long, but experience has shown that they are necessary safety precautions.

The use of community boars is dangerous. Numerous incidents of

the spread of the disease from an infected boar to healthy sows, and from diseased sows to a normal boar, have been reported

Control plans. As stated above, the standard blood test is not as accurate as desired for diagnosing brucellosis in the individual animal. Therefore, control is a herd problem rather than an individual animal problem. Since there is no cure, and neither test and immediate slaughter of the reacting swine nor vaccination have been satisfactory in the control of swine brucellosis, the following two plans of control are presented.

Plan 1. Sale of the entire herd for slaughter. This plan is useful in herds, large or small, where the primary consideration is the production of pork. It is quick, easy, and economical. An interval of 3 to 6 months may be necessary to dispose of the entire herd, feeder pigs and all, and to clean and disinfect the premises and equipment.

Replacement of the infected herd should be from herds free of brucellosis. Periodic blood tests should be conducted on the newly purchased herd as a means of detecting infection that might be about the premises. Brucellosis is primarily an animal-to-animal contact disease. Hence, early detection of animals that may become infected from the premises is essential to protect the new herd.

Plan 2. Test, segregation, and delayed slaughter of infected herd. The details of this plan are: (1) Blood test the entire breeding herd. (2) If infection is present, consider the entire herd as infected. Manage the herd as a unit. (3) Raise pigs from this infected unit. Wean and test the pigs at 8 weeks of age. Isolate the negative pigs on clean premises as far removed as possible from the infected parent stock. Maintain this isolation until the infected herd is disposed of. (4) Blood test the pigs at intervals of 60 days up to and during the first pregnancy. Remove all reacting pigs as they occur. Breed only those gilts which are negative to the blood test to noninfected boars. (5) Dispose of the original infected herd as soon as suitable negative replacements are available, or as soon as it is obvious that the plan is giving satisfactory results. (6) Premises where the infected herd was kept should be cleaned and disinfected thoroughly, preferably under supervision of a competent veterinarian, prior to establishing the clean replacement herd.

This last plan provides for the raising of negative pigs from the infected parent breeding stock so that clean replacements of known blood lines are available. Ultimate slaughter of the original infected herd is necessary, but may be delayed until the quality, quantity, and

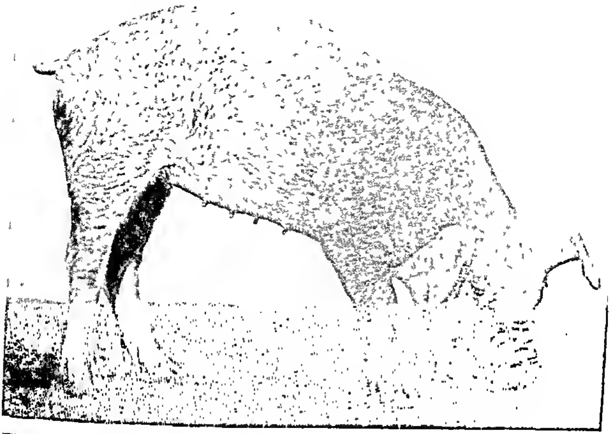


Fig. 109. Atrophic rhinitis. Note the deformed snout and thin condition *(courtesy, Ind. Exp. Sta.).*

often contains a cheesy substance. Bullnose is not likely to be serious unless the pigs have been anemic or debilitated in some other way.

Infectious rhinitis is often, if not always, serious in affected herds. The important economic loss caused by this disease results from the stunting effect it has rather than the death loss it causes. It is common for the disease to affect every animal in the herd and retard growth to such an extent that the herd is almost worthless.

For the control of this disease, it is recommended that the affected herd be disposed of completely for slaughter. Any measure short of this is apt to be disappointing since this type of rhinitis will probably be a perennial problem so long as any affected animals are kept. Breeding stock may carry this disease over from year to year and apparently spread it to successive litters of pigs.

HOG CHOLERA

In any discussion of diseases it is essential that cholera be [illegible] tioned because despite all the newer information on [illegible] hog cholera still looms as the biggest single disease [illegible]

the disease status of the pigs are known. This plan avoids the necessity of purchasing replacements from unknown sources, and also aids the breeder in maintaining desirable blood lines.

Transmissible gastro-enteritis. Transmissible gastro-enteritis is a highly infectious disease which may destroy practically the entire pig crop, particularly if the litters of young pigs are kept close together. The incubation period may be as short as 18 hours. This disease is uniformly characterized by scours, and there is often vomiting. Dehydration and loss of weight are rapid. Death commonly occurs in from 3 to 5 days after the first symptoms are seen. Older swine are sometimes affected. Brood sows may scour profusely and sometimes vomit, go off feed, quit giving milk, lose weight, and then usually recover in 4 or 5 days after the onset of the disease. The death loss in older animals is very low. No effective remedy or prevention other than isolation and sanitation has thus far been found.

The cause of this disease is a filterable agent, probably a virus. It is not related in any way to nutrition. Control is based on isolation and sanitation which help to stop the spread of infection. Sows which have not farrowed should be moved away from infected animals and should be separated as widely as possible.

Considerable discretion is sometimes needed in interpreting scours in pigs. While scours is a constant symptom in transmissible gastro-enteritis, it also occurs in other conditions, particularly in anemia.

INFECTIOUS RHINITIS

This disease is referred to as dystrophic or atrophic rhinitis (inflammation of the nose). The disease is reported to be caused by a virus and is evidently becoming more important as a disease of swine.

Clinically this type of rhinitis is characterized by violent sneezing and other evidences of irritation of the nose, such as rubbing the snout against various objects and pressing it into the ground. Bleeding from the nose may occur. There often is a well-marked deformity of the snout. The snout may be turned to either side or upward. An overshot lower jaw sometimes occurs.

Post-mortem examination reveals marked injury or complete destruction of some of the bones of the nose. In addition to the lesions in the nose, areas of necrosis and abscessation are sometimes found in the lungs.

Care should be taken to distinguish this disease from ordinary bullnose. Bullnose is characterized by a firm swelling on the snout which

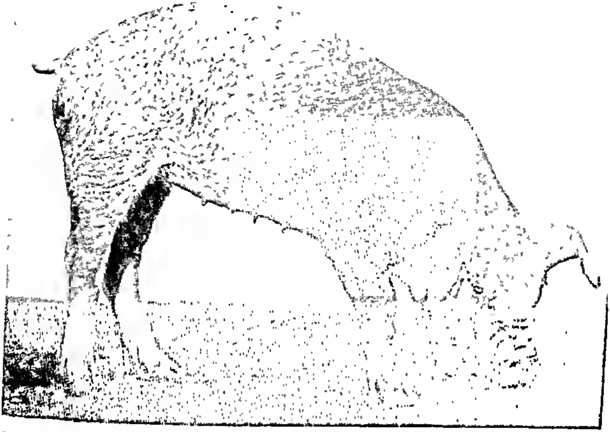


Fig. 109. Atrophic rhinitis. Note the deformed snout and thin condition *(courtesy, Ind. Exp. Sta.).*

often contains a cheesy substance. Bullnose is not likely to be serious unless the pigs have been anemic or debilitated in some other way.

Infectious rhinitis is often, if not always, serious in affected herds. The important economic loss caused by this disease results from the stunting effect it has rather than the death loss it causes. It is common for the disease to affect every animal in the herd and retard growth to such an extent that the herd is almost worthless.

For the control of this disease, it is recommended that the affected herd be disposed of completely for slaughter. Any measure short of this is apt to be disappointing since this type of rhinitis will probably be a perennial problem so long as any affected animals are kept. Breeding stock may carry this disease over from year to year and apparently spread it to successive litters of pigs.

HOG CHOLERA

In any discussion of diseases it is essential that cholera be mentioned because despite all the newer information on swine diseases hog cholera still looms as the biggest single disease factor in the future

Fig. 110. Bullnose. Note that the soft structures of the snout are involved, whereas in rhinitis the bones of the nose are involved *(courtesy, Ind. Exp. Sta.)*.

of a swine enterprise. In fact, cholera causes more loss to the swine industry than any other disease of hogs.

Unfortunately there is still no very reliable test for diagnosing cholera in the laboratory or the field; hence its diagnosis must be based on the history, symptoms, and lesions which vary from none to the typical textbook description. Judgment and experience are necessary for the accurate diagnosis of hog cholera. A practical rule to follow in considering swine trouble is that if swine sicken and die in large numbers, hog cholera should always be considered before other possible causes of death. This applies to vaccinated as well as unvaccinated herds.

Cholera symptoms. Cholera is caused by a virus. The virus is present in the blood of swine sick with cholera and is eliminated in the body secretions and excretions. The earliest symptom of hog cholera is a high body temperature. Loss of appetite, depression, and weakness occur in hogs that live several days after the rise in body temperature. Some die rather suddenly before these symptoms develop. Vomiting, diarrhea, labored breathing, gummy eyes, staggery gait, and dis-

colored or purplish skin are common symptoms. Cholera hogs lie in the bed most of the time and become thin and emaciated. They may be constipated at first, but are likely to scour later. Fits or convulsions are fairly common symptoms of cholera in young hogs.

The early symptoms of cholera resemble those of influenza and other acute infectious diseases. It is extremely important that an early correct diagnosis be made. The body temperatures of the apparently well hogs should be taken, and in case a large part of the apparently well portion of the herd have temperatures above 104°F, hog cholera should be suspected. Herds affected with cholera may be treated with cholera antiserum and virus, or with antiserum alone. It should be remembered, however, that visibly sick hogs will probably not recover and even some of the apparently well swine may die.

Vaccination. Hog cholera may be spread in many ways. No section of the Corn Belt is free of the disease. Outbreaks occur whenever feeder hogs are moved from the farm to livestock centers and back to the farm. Stockyards, sale barns, stock cars, trucks, garbage feeding, dogs, birds, men, wagons, automobiles, streams, and probably many other factors favor the spread of the hog-cholera virus. A very important factor in perpetuating hog cholera is faulty or careless vaccination. Cholera outbreaks are not uncommon in vaccinated herds. The only safe, sure way to control hog-cholera losses in infected areas is by means of effective vaccination. The most widely used method is the simultaneous use of anti hog-cholera serum and hog-cholera virus.

Vaccination can be done at any time, but it is usually better to vaccinate at or near weaning time. It is not desirable to vaccinate, castrate, ring, worm, and wean the pigs on the same day. A more satisfactory practice is to castrate at 3 weeks, vaccinate at 6 weeks and wean at 8 weeks of age. If pigs must be vaccinated under 6 weeks of age, animals kept for breeding should be revaccinated. Certain precautions should be taken before vaccinating with serum and virus. Ordinarily only healthy pigs are vaccinated. It is also advisable to reduce the feed for 12 hours prior to vaccination and to keep the pigs hungry for 10 days afterwards. Pigs should have access to clean quarters and plenty of fresh water at all times following vaccination.

In general, the losses from cholera which follow vaccination can be attributed either to poor virus, inadequate serum, or to the vaccination of sick pigs.

Crystal-Violet vaccination. Vaccination with Boynton's Tissue Vaccine (B.T.V.) and Crystal Violet Vaccine has gained some favor in

the last few years, but is not generally practiced as yet. One disadvantage in the use of these vaccines is the time required for immunity to develop following vaccination. From an idealistic standpoint these vaccines have certain advantages, chief of which is the fact that there is little or no danger of hog cholera being caused by their use. However, as yet the immunity produced does not appear to be as complete and lasting as when serum and virus are used.

ENTERITIS

Other than cholera, the most serious economic diseases of swine involve the intestinal tract and are commonly referred to as either enteritis or "necro." Enteritis means inflammation of the intestine, and "necro" refers to necrosis, or death of tissue. Hence, it should be readily understood that either enteritis, "necro," or necrotic enteritis are only lesions (tissue changes) and are not disease entities. Some progress has already been made toward an adequate understanding of enteritis, but there is still need for more exact knowledge of the subject. The most intelligent approach is to consider enteritis as an inflammation of the intestine and then attempt to find out what is causing the inflammation. In other words, it is not enough merely to have a diagnosis of enteritis or "necro" without trying to ascertain the precise cause of the enteritis.

In addition to transmissible gastro-enteritis, there are two important specific infectious diseases which cause an inflammation of the intestine. These are swine dysentery and hog cholera.

SWINE DYSENTERY

This disease is commonly referred to as bloody scours, bloody diarrhea, or black scours. Swine dysentery always causes an enteritis, more particularly, an inflammation of the cecum and colon. The clinical manifestations of dysentery are quite characteristic in that there is a diarrhea which is commonly called black or bloody scours. In young swine the bowel discharge usually contains mucous and easily recognizable blood. In older animals the blood in the bowel discharge may be changed so as to give the feces a dark color. The incubation period is usually from 1 to 2 weeks. Both longer and shorter incubation periods have been observed. The death loss is ordinarily considerably higher in young than in old swine. The average death loss is about 25 percent of the affected herd; however, it may vary from a few percent to 75 or 80 percent.

On post-mortem examination, the intestinal damage in dysentery

is found to be limited to the large intestine. There is sometimes an inflammation of the stomach. The damage to the intestine is characteristically superficial. There is not the deep damage of the intestinal wall that is sometimes found in cholera.

In order to reduce the spread of dysentery it is advisable to scatter the hogs as widely as possible. Although no specific effective medicinal or biologic remedy has been known in the past, the use of streptomycin or aureomycyin in the feed has shown promise in recent experiments. Following an outbreak of dysentery it usually is necessary to reduce the intake of corn and supply a bland diet, then gradually return the hogs to full feed. Recurrences of diarrhea are frequent in this infection. Ultimately, all hogs that have been exposed to the disease or that have recovered should be marketed. It is difficult to rid the houses and yards of infection. The manure and other litter in the yards should be removed and plowed underground. After cleaning and disinfection of the houses and removal of manure and litter from the yards and pastures, they should not be used for swine for at least 4, but preferably 6, months.

An early diagnosis is extremely important in the control of dysentery. It is advisable for the attending veterinarian to autopsy one or more of the sick hogs.

SWINE POX

Swine pox is caused by a virus and is widely distributed in the Midwest. It is an important disease of young pigs. The symptoms of pox are a partial or complete loss of appetite and an elevation of body temperature. Following these early symptoms, roundish vesicles or blisters and later scabs appear on the skin. These skin eruptions are most commonly seen on the ears, neck, undersurface of the body and inside of the thighs. Occasionally all parts of the skin are involved.

Perhaps the greatest danger associated with pox is that affected pigs may acquire pneumonia particularly when exposed to cold, crowded, and draughty quarters. Swine which show lesions of pox should not be vaccinated against cholera until complete recovery has occurred unless cholera threatens the herd.

The treatment of pox consists of feeding a light ration and supplying the hogs with clean, comfortable, dry sleeping quarters. In well-cared-for herds the death rate is usually very low. There is evidence indicating that lice may spread pox. Hence, the elimination of these parasites should help reduce the spread of the disease.

INFLUENZA

Influenza or swine "flu" is one of the most common infectious diseases of hogs. It is caused by a virus. The virus is present in the discharges from the nasal passages of affected swine. There are very few swine farms in the Corn Belt that do not have "flu" at least once a year. The disease occurs many times without known exposure to hogs which have influenza. In fact, the disease seems to appear on certain farms every year, which has led investigators to attempt to find the reason for such regular recurrences. It is now believed that the "flu" virus may reside in the eggs of the lung worm which are taken in by the common earthworm, which, in turn, is eaten by swine, resulting in a transfer of the virus. This could be a possible explanation of the carry-over of "flu" from year to year on farms.

Influenza is seen more frequently when the weather is changeable. Feeder hogs that pass through stockyards, sales barns, or other livestock centers may show symptoms of the disease when they arrive in the feed lot.

The most characteristic symptoms are high body temperature, prostration, and muscular soreness. Abdominal breathing or "thumps" is very often observed. An early diagnosis is essential in swine influenza, since forced exercise or handling increases the danger of death from pneumonia.

It is essential that influenza be distinguished from cholera. During the early part of an outbreak the history and symptoms may be similar and the veterinarian who examines the herd may, at first, have difficulty in determining the precise disease involved. If the symptoms are not characteristic, one or more sick hogs should be killed and examined by a competent veterinarian for post-mortem lesions.

Ordinarily the death loss from swine influenza is low in well-cared-for herds. There is no vaccine which will protect the hogs against influenza. The effective treatment for "flu" consists in reducing the feed and protecting the herd from exposure to cold. A quiet, well-bedded, comfortable place should be provided for the sick herd. It is also advisable to refrain from unduly exciting or handling any of the affected swine. The sick hogs should not be fed grain until they show signs of being hungry. Even then they should be brought back to full feed very gradually. Plenty of clean, fresh water conveniently located should be provided at all times.

It is often impossible to supply the best of facilities for sick hogs,

but swine "flu" is best handled by furnishing a liberal bed of straw and clean, well-ventilated quarters for the entire herd. A deep shed that is open on one side, usually the south, is a more desirable place for sleeping quarters than the farrowing house.

Influenza generally continues for 10 days to 2 weeks. A few hogs commonly develop broncho-pneumonia. These should be separated from the well hogs. The recovered hogs soon regain their weight if the caretaker is careful and uses good judgment in returning the swine to full feed.

TUBERCULOSIS

Tuberculosis is an infectious disease of mammals and birds. Cattle, hogs, and poultry are the farm animals most commonly affected. There are three types of the germ, the bovine, avian, and human; the first two commonly infect hogs. Previous to the accreditation of the Central and North Central States for cattle tuberculosis, swine tuberculosis of cattle origin was common. At the present time the poultry type is responsible for most of the condemnations in abattoirs where federal inspection is maintained.

The bacillus of tuberculosis invades the body tissues and destroys them. The characteristic lesion of the disease is the tubercle. The tubercle is small at first, but increases in size as the disease progresses. In advanced or generalized tuberculosis, masses of tuberculous tissue form in the lymph glands, liver, lungs, spleen, and other organs. In open cases of the disease tuberculous material is discharged into the air passages, intestine, and milk ducts. Pigs become infected by nursing tuberculous sows. Chickens and turkeys that have tuberculosis infect hogs if allowed to range in the hog lots and pasture. Hogs that follow tuberculous cattle often suffer from generalized tuberculosis.

Tuberculosis cannot be diagnosed in the early stages of the disease by the symptoms alone. The only reliable way to diagnose the disease is to test the herd with tuberculin. Herds in which generalized cases of tuberculosis are found on autopsy should be tuberculin-tested by a veterinarian. All hogs that are shown to have tuberculosis may be slaughtered under federal inspection. Young hogs or pigs that react to the test should be slaughtered and their carcasses disposed of by burning. The nonreacting hogs may be moved to clean ground and retested at 60-day intervals until they have passed two clean tests. It is advisable to vacate the central hog house and yards for from 6 to 12 months. Quarters that can be thoroughly cleaned may be used

in about 6 months after all manure and other litter are removed to a safe place or burned and the house disinfected.

It is not difficult to maintain a tuberculosis-free herd. All breeding hogs added to the herd should be tuberculin tested. Poultry should not be allowed free range or contact with hogs unless the birds are known to be free from tuberculosis. Hogs that follow feeding cattle should not have any contact with the breeding herd. The by-products of creameries and cheese factories should not be fed to hogs without pasteurization. Garbage collected in towns and cities should be cooked before feeding it to hogs.

BREEDING TROUBLES

Since swine produce a number of offspring at one time, estimates of fertility are difficult to make. Complete sterility in swine is apparently less frequent than in cattle, but lowered fertility is known to occur.

Fig. 111. Orchitis (inflamation of the testicle) due to brucellosis *(courtesy, Ind. Exp. Sta.)*.

Reproductive failures in swine may be due to various factors. The information available calls attention to the problem in swine, but few specific measures for the correction of infertility have been described. It should be pointed out that certain defects in reproduction may be hereditary and, therefore, are not amenable to treatment. Treatment of infertility in individual swine is often of doubtful economic value.

When infertility is encountered as a herd problem, the veterinarian should endeavor to find the cause or causes and then attempt to prevent or control the condition.

Reproductive failures may result from (1) inability or reduced ability to produce ova (eggs) by the sow or sperm cells by the boar, (2) lack of sexual desire, (3) death of ova or sperm cells prior to fertilization, (4) failure of implantation of fertilized ova in the uterus, (5) arrested or abnormal fetal development, abortion, or fetal resorption, and (6) stillborn pigs at full term. The incidence of these various causes of infertility are not completely known.

Studies conducted on sows indicate that of the ova shed, about 36 percent are not fertilized; 19 percent die between conception and parturition and 16 percent of the pigs die between parturition and weaning. Thus, of the 15 to 40 ova produced by a sow at the time of estrus (heat), only approximately 30 percent are represented by live pigs at weaning time.

The percentage of stillborn pigs averages about five percent. Asdell and Williams [1] reported an incidence of 6.6 percent stillborn pigs, exclusive of mummified fetuses, in a total of 1882 pigs born over a 5-year period. They associated large litters and old sows with high numbers of stillborn. More stillbirths were recorded in spring litters, of which many showed iodine-deficiency symptoms. Of 127 stillbirths, 8 were attributed to immaturity, 18 to over- or undersized organs, 19 to pathologic conditions, 19 to endocrine disturbances, 5 to deformed skeleton, 13 to accidents during birth, and 45 unclassified. Microscopic examination of lungs revealed a preponderance of open or partially open air sacs. This finding, coupled with the fact that 9 stillbirths were recorded in the first half of the litters born, and 45 in the second half, led the authors to consider suffocation during birth as an important cause of death. It has been observed many times that the number of stillborn pigs increases with the length of parturition. Attempts by Asdell and Williams to hasten parturition with pituitrin gave inconclusive results, although initial success suggested further trials should be made.

Excessive use of either young or old boars often results in reproductive failures. Allowing the boar to run with sows whereby he may perform several matings a day often results in small or fewer litters. It has been shown that even two services per day may be undesirable.

[1] S. A. Asdell and J. P. W[illegible], "The Causes of [illegible] to Control It," *J. Agric. Res.*, 63, 34[illegible] (1941)

since the second ejaculate is smaller, and the testes require a rest to restore normal sperm-cell formation.

Cryptorchism. Cryptorchism (retention of one or both testicles in the abdominal cavity) in male swine is an inherited characteristic. McPhee and Buckley[2] claim that most of the evidence on cryptorchism can be accounted for on the basis of a monogenic sex-limited recessive. They showed that in six generations of brother-sister mating there were about 40 cryptorchids, both unilateral and bilateral, out of some 250 boars. The only certain method of eliminating cryptorchism is by discarding all animals which have been the parents of cryptorchids.

Pathologic conditions affecting reproduction. Concretions and preputial calculi occasionally occur in the male, resulting in difficult urination and inability to protrude the penis. These conditions are easily detected and are not difficult to correct. Screwworms may infest the prepuce and cause swelling and distress to the animal.

Specific reproductive diseases of swine have not been studied extensively. *Metritis* (inflammation of uterus or pig-bed) is not so common in the sow as in the larger animals. Retention of the placenta (afterbirth) is also less frequent and may be a factor in the lowered occurrence of metritis. Recommended treatments consist of irrigation and removal of the offending material which is attended by some difficulty due to the small size of the genital organs.

Vulvo-vaginitis has been reported in Australian and American literature and observed by many workers. Females of all ages are affected, even the suckling pig. The cause is not definitely known, but a similar, if not identical, condition has appeared in herds where moldy corn and moldy barley were being fed. Marked enlargement of the vulva is usually accompanied by symptoms of estrus, a catarrhal exudate, and general unthriftiness of the affected pigs. Accompanying prolapse of the rectum is not uncommon, and the death rate is said to be high. Treatment consists of discontinuing the feeding of moldy corn or other suspected feeds.

RHEUMATOID CONDITIONS OF SWINE

The condition or conditions which are here designated as rheumatoid disease include joint and skin lesions as well as heart lesions and some lesions of the other vital organs which are commonly seen in

[2] H. C. McPhee and S. S. Buckley, "Inheritance of Cryptorchism in Swine," *J. Hered.*, 25, 295–303 (1934).

swine. These disease manifestations appear to be somewhat similar to rheumatic and rheumatoid disease in the human.

The importance of this condition, or these conditions, is generally recognized. Many hog growers find it difficult at times to raise swine profitably because the animals develop rheumatoid conditions. The damage done in affected herds is extremely variable. The occurrence

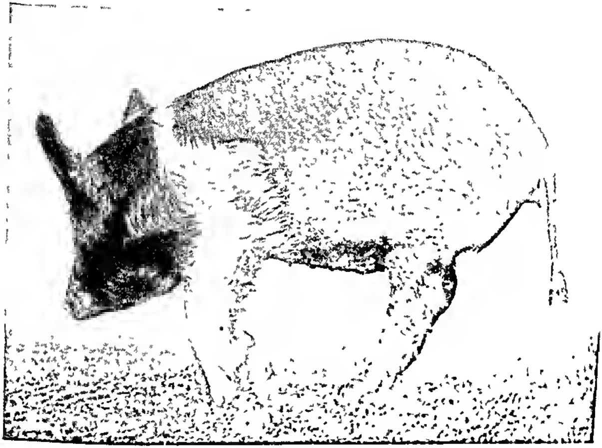


Fig. 112. A pig afflicted with a rheumatoid condition similar in many respects to arthritis in humans (*courtesy, Ind. Exp. Sta.*)

or reoccurrence of the disease is unpredictable. In some herds less than 1 percent of the swine are affected. In other herds more than 10 percent are seriously affected.

The clinical symptoms are quite variable. In some early cases the body temperature may be as high as 108 F. Some of the acute cases show few other symptoms and sometimes they make spectacular recoveries without any treatment. Frequently there is evidence of weakness or stiffness which suggests muscular and joint pain. A severe shifting lameness may be observed. In the early stages the animal may be unable or unwilling to walk. In white or light-colored swine skin lesions may be conspicuous. These skin lesions may be [illegible]

areas of redness or they may be diffuse. These reddened areas are usually hard and may slough at a later time.

In the chronic stage, rheumatoid disease is mostly evidenced by joint lesions, which are quite conspicuous. The joints become enlarged especially the knee and hock. The amount of disability depends to a large extent on the degree of damage in the joint.

The death loss is usually low, but the stunting and unthriftiness are serious and result in economie losses.

Erysipelas. It is probably already apparent that the disease condition or eonditions described here correspond to what is being called swine erysipelas, attributed to infection by the bacterium *Erysipelothrix rhusiopathiae.* The question of the cause of rheumatoid disease or swine erysipelas is in need of critical re-examination. In other words, there is rather general agreement that it is difficult or impossible to cause the disease in swine with cultures of Erysipelothrix rhusiopathiae experimentally. Recommendations for handling this condition must await further research as to its precise cause.

CASTRATION

The owner or herdsman usually takes the responsibility of castration of the male pigs. Many swine raisers do not employ a veterinarian and, unfortunately, the operation is often performed in a careless and harmful manner.

Pigs may be castrated when very young or up to a few months of age. It is usually not advisable to castrate pigs at weaning time because the effect of both weaning and castration is apt to be sufficient to retard growth. The castration of older boars is best left to the veterinarian, since he has the necessary equipment and is better able to perform the operation with greater safety to both the animal and the operator.

Castration may be performed at any time of the year, but it is well to consider that screwworm infestations may occur in the summer months. Such complication will make castration results extremely unsatisfactory. All cases of scrotal hernia should be operated by a veterinarian.

PLANT AND OTHER POISONING

Young cockleburs and water hemlock are the most common causes of plant poisoning in swine. The poisonous principle in water hemlock is concentrated in the roots and young shoots. Young cockleburs in

the two-leaf stage are poisonous. Poisoning from these plants is most common in the spring and early summer; however, occasional wet, warm periods in the fall may result in young shoots starting again with resultant poisoning.

In water-hemlock poisoning the symptoms are nervousness, muscular twitching, and severe convulsions followed by death. The symptoms of cocklebur poisoning are depression, vomiting, staggering, and labored respiration. Death follows in a few hours.

In suspected plant poisoning, the pastures and lots should be examined carefully for weeds. Water hemlock grows most commonly along small streams, while young cockleburs are usually found in washed-out areas of the pasture.

One or more of the dead or sick hogs should be examined post mortem by a veterinarian. If the examination reveals no evidence of an infectious disease and the pastures are found to contain poisonous weeds, some of which have been eaten, the entire herd should be moved to safe premises.

Other toxic substances frequently reported as being the cause of swine troubles are salt, protein, and pitch.

The evidence regarding salt poisoning is not clear. In experimental trials salt has failed to poison hogs even when salt had been withheld for several weeks. Under certain conditions, which were not present in these experiments, salt may be injurious to swine. Swine raisers should not avoid feeding salt in the ration because it has been shown to be of value in the diet especially in reducing the cost of weight gains. The belief that protein poisons hogs has even less support than salt poisoning.

If swine eat pitch from any source, poisoning and death may be the result. Several cases have occurred where swine were turned into pastures formerly used for trap shooting. This poisonous material may remain in the fields for years. Several cases have occurred where pitch products were used to coat pipes.

Accidental cases of poisoning by such substances as paris green and mercury have occurred. Paris green, in these cases, was being used as an insecticide, and mercury in the treatment of seed. Potential danger of present day rat poisons should be considered when using these substances where there are swine.

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Production and feeding qualities of peanut oil meal. From 1939 to 1948 inclusive the annual production of peanut oil meal used as feed in the United States varied from a low of 30,000 tons in 1939 to a high of 137,000 tons in 1940. The average was 90,000 tons, a relatively limited amount when compared with the production of the other oil meals.[32]

Hydraulic-press peanut oil meal is very similar to cottonseed meal in composition, but contains no toxic principle. As shown in Table 133, it contains 43.5 percent of protein, 7.6 percent of fat, with about 13 percent of fiber. Meal produced by the solvent extraction process, which is limited, the protein content is 51.5 percent, the fat 1.4 percent, and the fiber 5.7 percent.

Being rich in protein and palatable, this meal should have an important place in southern pork production. Like the other protein concentrates of plant origin, however, or of most any other single supplement for that matter, it is lacking in many of the minerals and vitamins which are necessary to balance completely the home-grown grains. The quality of the proteins contained in peanuts is rated fairly high.

Peanut oil meal and fish meal compared. In four separate experiments Foster and Hostetler of the North Carolina Station [33] compared peanut oil meal and fish meal when fed as single supplements to shelled corn and minerals to pigs averaging about 83 pounds at the start for a period of 68 to 98 days under dry-lot conditions. The corn, supplements, and minerals were self-fed, free-choice. The results, averaged for the four trials, are summarized in Table 136.

The pigs fed the fish-meal supplement made significantly faster and more economical gains. The peanut meal proved unusually palatable, however, for it was consumed in the ratio of 1 part to 2.8 parts of corn, a quantity which was considerably in excess of the amount necessary to supply the protein needs. The cost of 100 pounds of gain, with peanut meal priced at $42 a ton and the fish meal at $54 a ton, was $7.13 for the peanut-meal ration and $6.62 for the ration containing the fish meal. The principal reason for the faster and more economical gains of the pigs receiving the fish meal was, no doubt, the fact that the ration was less deficient in the B-complex and related vitamins, especially those represented by the APF factors.

For the most efficient use of peanut oil meal as a protein concen-

[32] *Feed Statistics*, U.S.D.A., Bu. Agr. Ec., Statistical Bul. 85, 1949.
[33] J. E. Foster and Earl H. Hostetler, Tech. Bul. 56, 1938.

Table 136. Peanut Oil Meal versus Fish Meal for Pigs in Dry Lot
(Average 4 Experiments)

Rations	*Initial Weight per Pig*	*Daily Feed Consumption per Pig*	*Daily Gain per Pig*	*Feed Required to Produce 1 Cwt. Gain*	
	lb.	lb.	lb.		lb.
Sh. corn, peanut oil meal, and minerals, self-fed, free-choice	83	5.25	1.32	Corn	309.4
				Peanut o.m.	110.8
				Minerals	4.59
				Total	424.79
Sh. corn, fish meal, and minerals, self-fed, free-choice	83	6.45	1.62	Corn	356.5
				Fish meal	35.5
				Minerals	3.04
				Total	395.04

trate in swine rations, it must be fed with other supplements, preferably of animal or fish origin, and along with feeds which supply ample vitamins, together with provisions for an adequate supply of minerals. Supplemental mixtures, such as equal parts of peanut oil meal and fish meal; one-third each of peanut oil meal, meat scraps, and soybean oil meal; and two parts peanut oil meal, one part tankage, and one part cottonseed meal constitute efficient combinations when fed in a grain ration containing 10 to 12 percent by weight of high-quality alfalfa or other legume meal or green forage, and when fed along with a simple or complex mineral mixture as conditions suggest.

Peanut oil feed or whole pressed peanuts, since it includes the hull, contains much more fiber and less protein than peanut oil meal. Its feeding value as a protein supplement consequently is of a lower order. To supply the same amount of protein, it is necessary to feed 25 percent more of the feed than of the meal. Making allowance for this difference, peanut oil feed may be substituted for peanut oil meal in the above mixtures with the expectation of satisfactory results.

CORN GERM MEAL; CORN OIL MEAL

Definitions. The American Feed Control Officials define *corn germ meal* as the dried and ground portion of the corn germ and other parts of the corn kernel from which part of the oil has been pressed; it is the product obtained in the dry-milling process of manufacture of corn meal, corn grits, hominy feed, and other corn products. It sometimes

goes under the name of hominy corn germ meal. *Corn oil meal* is the ground product obtained from the corn germ from which part of the oil has been pressed in the wet milling process of manufacture of corn starch, corn syrup, and other corn products. This is sometimes called starch corn germ meal. In the wet milling process, a weak water solution of sulphurous acid is used to facilitate the separation of the germ from the kernel, which sometimes results in imparting an acid taste to the meal.

Corn by-products are not popular. These corn by-products have not been extensively used as such in pork production. Most of the available supply finds its way into rations for dairy cows and into commercial mixed feeds. As supplements to corn, they have definite limitations, more pronounced than those characteristic of plant protein concentrates generally. It contains less than half as much protein as either soybean oil meal or cottonseed meal, and less than two-thirds as much as linseed meal. Since the proteins contained in these corn by-products cannot be expected to supplement in any way the amino-acid deficiencies of corn, the quality of the protein contained in a corn-corn oil-meal ration is of extremely low biological value. The calcium deficiency is more pronounced than in any of the other mill by-products, and their supply of vitamins is as inadequate.

Some experimental studies. Skinner and Starr of the Indiana Station [34] studied methods of feeding corn germ meals to well-grown pigs in the dry lot. They found that so-called starch corn germ meal (corn oil meal) was unpalatable and that it could not be used profitably either as a substitute for, or as a sole supplement to, corn. Starch corn germ meal and tankage produced less than half the gains made by pigs receiving corn and tankage. When fed as a supplement to corn, with charcoal and salt, in the ratio of 1 part starch corn germ meal to 3 to 7 parts corn, fair results were obtained. Compared with the results from the lot fed corn and tankage, however, they were not so profitable. When fed as a substitute for a part of the tankage in a corn-tankage ration, both kinds of germ meal gave fairly good results. A supplement of 1 part starch corn germ meal and 1 part tankage, or one of 3 parts of hominy corn germ meal and 1 part tankage, fed with corn, gave as rapid and as economical gains as were obtained with corn and tankage.

Robison of the Ohio Station [35] secured a gain of 1.25 pounds daily

[34] J. H. Skinner and C. G. Starr, Bul. 219, 1918.
[35] W. L. Robison, Bul. 349, 1921.

with pigs fed a ration of 3 parts corn and 1 part corn germ meal on rape forage. The results were not quite as satisfactory, however, as those obtained with a ration of 8 parts corn and 1 part linseed oil meal, or of 7 parts corn and 1 part soybeans. In a dry-lot experiment a ration of 2 or 3 parts corn meal and 1 part corn germ meal, with minerals, did not give as good results as other corn rations balanced with linseed oil meal, peanut meal, fish meal, or tankage fed under the same conditions. Evvard and Culbertson of the Iowa Station [36] self-fed a combination of 1½ parts corn germ meal and 1 part tankage in comparison with tankage alone, self-fed, with corn to growing and fattening pigs on rape forage. The pigs which received the mixed supplement gained nearly as rapidly as those fed tankage. To produce a unit of gain, however, the germ meal had a value but little more than one-half that of the tankage fed as the sole supplement.

COCOANUT OR COPRA OIL MEAL

a unit of gain. It was calculated that the meal had a value 15 percent greater than that of corn.

In further trials he determined that cocoanut meal had a much higher value when fed at a level of 25 percent of the ration than when fed in larger amounts; also, that its value was much higher when replacing part of both the corn and protein concentrate than when replacing all the corn or all of the protein concentrate.

CORN GLUTEN MEAL; CORN GLUTEN FEED

Corn gluten feed is the principal by-product produced in the manufacture of corn starch and represents those parts of the corn kernel which are left after most of the starch and germ has been removed. It contains most of the gluten and bran with adhering starch particles. Usually the so-called corn solubles, and sometimes the corn oil meal, are added. *Corn gluten meal* is equivalent to corn gluten feed without the bran. It is consequently a more concentrated product and is better adapted to the pig's capacity than the more bulky gluten feed.

Composition of corn by-products. Corn gluten feed has an average analysis of 25.5 percent of protein, 48.8 percent of nitrogen-free extract, 7.6 percent of fiber, and 2.7 percent of fat. Corn gluten meal has 43.1 percent of protein, 39.8 percent of nitrogen-free extract, 4 percent of fiber, and 2 percent of fat.[39] Both are seriously deficient in calcium and common salt and, like the other protein feeds of plant origin, are lacking in most of the critical vitamins. The protein quality of these feeds when fed in a corn ration is, of course, inferior.

Experimental feeding results. Although sufficiently rich in protein to indicate some value as a supplement to corn or other grains, these by-products have not proved successful in practice. Evvard and Dunn of the Iowa Station [40] did not get satisfactory results when gluten feed, either as a substitute for, or a supplement to, corn was fed to growing and fattening pigs on rape pasture. They were decidedly inferior to a ration of corn and tankage; in fact, the ration of corn and gluten feed did not produce as rapid nor as economical gains as did corn alone. Evvard [41] also tried to substitute gluten feed for part of the tankage in a corn-tankage ration for growing and fattening pigs in the dry lot. In no instance did the gluten feed prove to be a profitable addition. In

[39] F. B. Morrison, *Feeds and Feeding*, 21st ed., Table I, Appendix, 1948.
[40] J. M. Evvard and R. Dunn, Mimeo. Rpt., 1917.
[41] J. M. Evvard, Leaflet 18, 1926.

still another test at the Iowa Station, Culbertson and associates [42] found that the substitution of gluten feed for one-half a supplemental mixture composed of 70 percent tankage, 25 percent linseed oil meal, and 5 percent alfalfa meal for pigs fed to market weight in the dry lot was not an economical procedure. Similar studies made by Ashby of the Minnesota Station gave very much the same results.

Aubel and Alexander of the Nebraska Station [43] secured fairly satisfactory results with a ration of corn and gluten meal when fed to growing and fattening pigs on alfalfa pasture, but the gains were not so rapid as on corn and tankage. When a ration of corn, gluten meal, and alfalfa hay was compared with one of corn, tankage, and alfalfa hay, the pigs which received the gluten meal did not gain half as fast as those fed tankage.

[42] C. C. Culbertson, J. M. Evvard, W. E. Hammond, and C. F. Bassett, Leaflet 18, 1926.
[43] C. E. Aubel and M. A. Alexander, Mimeo. Rpt., 1929.

XV The Cereal Grains and Other Carbonaceous Feeds

The large pork-producing capacity of the United States is made possible through the production of cereal grains greatly in excess of the needs of the human population for food. Of the cereal grains fed to all classes of livestock from 1930 to 1944 inclusive, 33 percent was consumed by hogs.[1] Jennings[2] estimated that of all feeds fed to hogs from 1940 to 1947, inclusive, corn constituted approximately 73 percent of the total, oats 8 percent, other grains (barley, wheat, rye) 11 percent, commercial by-products 5 percent, and seeds (soybeans, peanuts, etc.) and skim milk (dry basis) 3 percent.

PRODUCTION AND PRICES OF THE CEREAL GRAINS

As shown in Fig. 55 the production of corn greatly exceeds that of the other cereals. Since 85 to 90 percent of this corn is available for feeding, whereas only 10 to 15 percent of the wheat and 25 to 30 percent of the rye normally is so available, the dominating position of the corn crop in relation to pork production is emphasized. Corn production during the 10-year period, 1940 to 1949, exceeded by 29 percent the production during the previous decade, 1930 to 1939, incidentally the result of increased yields rather than because of an increase in acreage. Five times during the latter period the annual production has exceeded three billion bushels.[3]

The average annual farm prices per bushel for the 10-year period 1939 to 1948 are shown in Fig. 56. The price changes from year to year of the different grains parallel one another rather closely and

[1] C. W. Crickman, *Feed Grains and Meat Animals*, U.S.D.A., Bu. Agr. Ec., F. M. 51, 1945.
[2] R. D. Jennings, *Relation Between Feed, Livestock, and Food at the National Level*, U.S.D.A., Bu. Agr. Ec., Cir. No 836, 1949.
[3] *Feed Statistics*, U.S.D.A., Bu. Agr. Ec., Statistical Bul. 85, 1949.

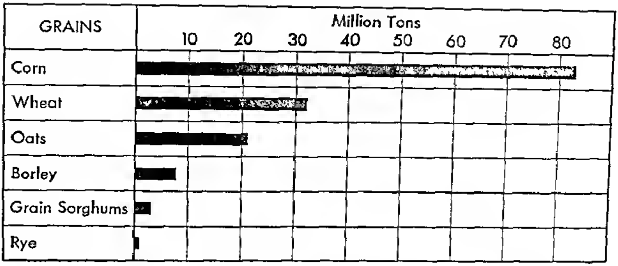

Fig. 55. Average annual tonnage production of principal cereal grains in United States, 1940 to 1949, inclusive.

coincide with the general level of farm commodity prices. Although total production increased somewhat during the period, consumption requirements, as a result of the war, increased at a much greater rate. Following the war, the general economic conditions, together with the

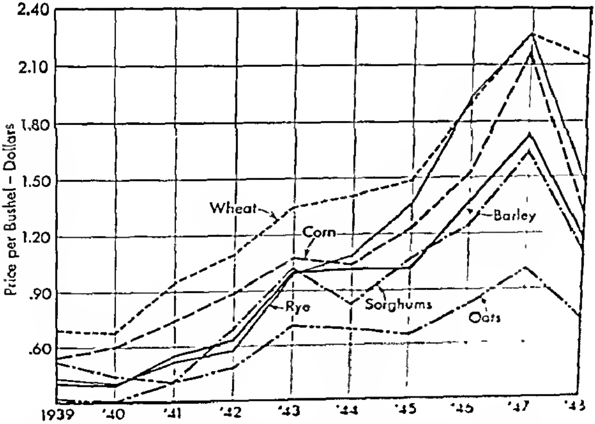

Fig. 56. Average annual farm prices of cereal grains in the United States, 1939 to 1948, inclusive (Feed Statistics, *U.S.D.A., Bu. Agr. Ec., Statistical Bul* 85, 1949).

Government's price-support program, were responsible for price inflation during the postwar period, and a high general price level was the result.

The average monthly farm prices of these grains per hundredweight from 1939 to 1948 inclusive are shown in Fig. 57. The prices received by farmers for all the grains dropped from January to February, following which they tended to advance until the beginning of the harvest season for the respective crops, after which a tendency to decline for

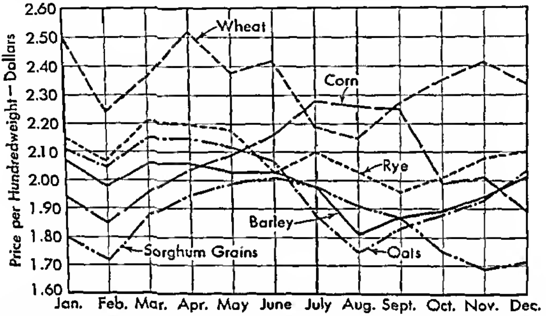

Fig. 57. Average monthly farm prices of the common cereal grains in the *United States, 1939 to 1948, inclusive (Feed Statistics, U.S.D.A., Bu. Agr. Ec., Statistical Bul.* 85, 1949).

a time is apparent. The price of corn varied from month to month more widely than that of any of the other grains. The seasonal or prospective seasonal demand on the available or prospective seasonal supply normally may be expected to determine the price at any given time.

Composition of the cereal grains. The deficiencies of corn and the other cereal grains in meeting the nutritional requirements of the pig have been discussed in some detail in Chapters VII and VIII. Some but not all of these deficiencies are revealed by the usual chemical analysis, as shown in Table 137.

These grains are all characterized by a very high carbohydrate content, a rather low supply of protein, and a marked deficiency of the important mineral element calcium. They also are deficient in most of the other minerals, especially of common salt. The protein quality

Table 137. Composition of the Cereal Grains[4]

Grains	Dry Matter	Crude Protein	N-free Extract	Fiber	Fat	Calcium	Phosphorus
	%	%	%	%	%	%	%
Corn	85	8.6	69.3	2.0	3.9	0.02	0.27
Wheat	89.5	13.2	69.9	2.6	1.9	0.04	0.39
Oats	90.2	12.0	58.6	11.0	4.6	0.09	0.34
Oat kernel	90.0	15.4	65.7	2.6	4.2	...	...
Barley	89.4	12.7	66.6	5.4	1.9	0.06	0.37
Rye	89.5	12.6	70.9	2.4	1.7	0.10	0.33
Emmer	91.1	12.1	63.6	9.8	1.9	...	0.33
Kafir	89.8	10.9	72.7	1.7	2.9	0.02	0.31
Milo	89.4	11.3	71.3	2.2	2.9	0.03	0.30

generally is only fair and concerns, especially in the case of corn, the supply of the amino acids lysine and tryptophane. The grains as a whole are lacking in vitamins A and D, with the exception that yellow corn contains considerable vitamin A value, but are good sources of thiamine or vitamin B1. The supply of most of the vitamins belonging to the B2-complex is considerably below the amount necessary to meet the nutritional needs of the pig, and there appears to be a total lack of those vitamins that have been associated with the animal protein factor.

These observations emphasize the fact that in order to function efficiently in swine rations these carbonaceous grains must be adequately supplemented by the addition of sources of these necessary missing ingredients.

CORN

In the following sections of this chapter the cereal grains and other carbonaceous feeds are discussed and the results of experimental feeding trials summarized in which they have been fed as substitutes for corn or in comparison with it. Since the feeding of corn to all classes of hogs has already been considered in the previous chapters and is the standard with which the other grains are compared in this chapter, there remains to consider here only the questions of grinding, soaking, etc.

Grinding corn for well-grown fattening pigs. Early experiments at the Iowa[5] and Indiana Stations[6] showed that, for well-grown fatten-

[4] F. B. Morrison, *Feeds and Feeding*, 21st ed., Table 1, Appendix, 1948.
[5] W. J. Kennedy and E. T. Robbins, *Bul. 106, 1909.*
[6] F. G. King, Am. Soc. An. Prod., 1914.